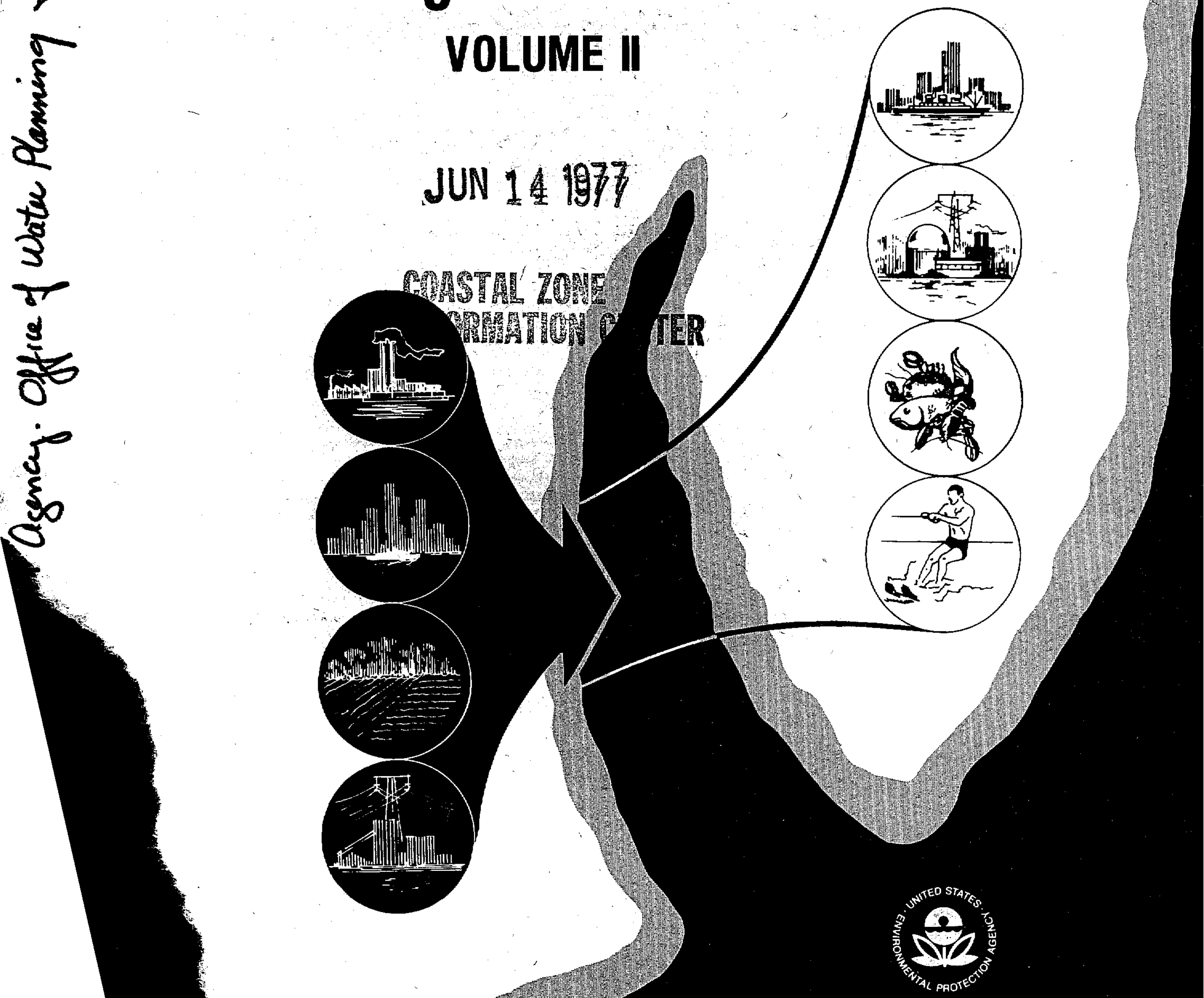
ESTUARINE POLLUTION CONTROL AND ASSESSMENT

Proceedings of a Conference

VOLUME II



U. S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF WATER PLANNING AND STANDARDS
WASHINGTON, D.C.

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OTHER POLLUTANTS

OIL POLLUTION IN THE COASTAL ENVIRONMENT

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ABSTRACT

Petroleum and petroleum products such as fuel oil and lubricating oil are very complex mixtures of chemicals with individual compounds numbering at least in the tens of thousands. This very complex chemical mixture is introduced into the already complex system of interacting physical, chemical, biological, and geological components which constitute the marine environment. Thus, the investigation of the impact of oil pollution on the marine environment is a difficult undertaking which will require much more research before some of the potentially most serious problems are fully understood.

INTRODUCTION

Oil pollution in the estuarine and coastal environment is the subject of many strong political, economic, and environmental arguments. The advent of new and/or expanding refinery operations, port facilities, deepwater oil terminals, offshore drilling and production, pipelines, ocean dumping, and tanker traffic requires an understanding of the impact of accidentally or intentionally discharged oil on the coastal zone environment.

A major portion of our knowledge about oil pollution has been obtained during the past five years. The acquisition of this knowledge was catalyzed by such well publicized incidents as the massive Torrey Canyon oil tanker spill, the Santa Barbara oil well blowouts and smaller but extensively studied spills such as the West Falmouth, Mass., oil spill (Anon., 1971; Smith, 1968; Straughan and Kolpack, 1971; Blumer et al., 1971a).

The findings of many oil spill studies and laboratory and field surveys of oil pollution are subjects of serious debate within the scientific community, and also within the governmental, public, and private sectors of the world. The controversy involving seemingly conflicting reports about the impact of oil pollution resulted in the convening of a study group by the National Academy of Sciences to ascertain the state of our knowledge with respect to the inputs, fates, and effects of oil pollution in the marine environment and to point to areas in need of further research. The study group met in May 1973. The report will be issued late in 1974 or early 1975 after more than a year of debate and revision. It is clear after reading the final drafts of this report and also the background papers (NAS, 1973, 1974) leading to the first draft, that areas of controversy remain. It is also clear from reading these same reports and reviewing current literature that significant progress towards understanding the inputs, fate, and effects of oil in the marine environment has been achieved.

OBJECTIVES

The objectives of this paper are as follows:

1) To provide a summary of available information.
2) To discuss areas of controversy and areas of limited knowledge.
3) To suggest information which can be of use in making management decisions regarding the estuarine and coastal environment.
4) To suggest some approaches towards providing the further information needed to adequately understand and/or monitor oil pollution.

A review and discussion of the engineering aspects of the prevention, control, and abatement of oil pollution will not be attempted. They are subjects better treated by someone more knowledgeable in the field of engineering. Readers interested in these topics will find them discussed in the Proceedings of the Conferences on the Prevention and Control of Oil Pollution (API, 1969, 1971, 1973).

SOURCES OF INFORMATION

There are numerous sources of published information about oil pollution. These sources include newspaper accounts, technical reports, and refereed scientific journal publications. Generally, the latter is the information source most highly regarded for its accuracy and objectivity. Scientific journal articles are usually rigorously reviewed by the authors' peers prior to acceptance for publication. There are numerous scientific journal articles dealing with oil pollution. There are, however, far more technical reports reporting on oil pollution studies. The preponderance of technical reports is the result of the need to get information to decision makers, including the public, as rapidly as possible. If a scientist waited for the normal review and publication process in a scientific journal he would experience a delay of approximately 6 to 18 months after writing a report of the study. The demands for information often require a more rapid transfer process from the arena of science to that of decision makers. But a penalty is paid. The peer review process is circumvented unless the decision makers arrange for peer review of the report. They are well advised to do so, including peer review of this report.

It is fortunate that, as previously mentioned, the subject of oil pollution in the marine environment has recently been reviewed by the National Academy of Sciences study group. Readers interested in a detailed review of the subject are referred to the Background Papers for this study and the Final Report (NAS, 1973, 1974). There are also several other reports from workshops, symposiums, or conferences, and books which provide a broad review of the literature or contain in one collection several papers on recent progress (API, 1969, 1971, 1973; Duce and Parker, 1974; Goldberg, 1972 a, b, c; Ketchum, 1972; SCEP, 1970; Smith, 1974; NAS, 1971; Mathews et al., 1971; Hoult, 1969; Boesch, et al., 1974).

Two large collections of references dealing with oil pollution studies are those of the Oil Spill Information Center, University Library, the University of California, Santa Barbara; and the Plymouth Laboratory of the Marine Biological Association of the United Kingdom. I have avoided listing an extensive bibliography because there are over 2,000 references dealing with the various aspects of oil pollution contained in the files of the two bibliographic collections, books, reports, and papers cited above. Rather key references or references to reviews are given.

Table 1.—Estimate of petroleum and petroleum hydrocarbon inputs to the marine environment

(Millions of metric tons per year)

	World	U.S.
Normal Operations		
Offshore Production [a]	0.02	0.003
Transportation [a]		
Load on top tankers	0.31	0.05
Non-load on top tankers	0.77	0.12
Dry docking	0.25	0.039
Terminal operations	0.003	0.0004
Bilges bunkering	0.5	0.078
Coastal Refineries [a]	0.2	0.03
Coastal Municipal Wastes [a]	0.3	0.10
Coastal Non-Refinery Industrial Wastes [a]	0.3	0.10
Urban Runoff [b]	0.3	0.10
River Runoff [b]	1.6	0.53
Atmosphere [c]	0.6	0.18
Natural Seeps [b]	0.6	0.12
Accidents [a]		
Offshore production	0.06	0.01
Tankers	0.2	0.03
Non-tankers	0.10	0.02
	6.113	1.510

[a] Estimate with high confidence rating.
[b] Estimate with modest confidence rating.
[c] Estimate with low confidence rating.

Table 2.—United States petroleum and petroleum hydrocarbon inputs to the marine environment

	Million Metric Tons per Year	% of Total
Offshore Production		
Normal operations	0.003	0.20
Accidents	0.01	0.66
Subtotal	0.013	0.86
Tankers		
Normal operations	0.209	13.84
Accidents	0.03	1.99
Subtotal	0.239	14.73
Non-Tankers		
Bilges bunkering	0.078	5.17
Accidents	0.02	1.32
Subtotal	0.098	6.49
Coastal Refineries	0.03	1.99
Coastal Municipal Wastes	0.10	6.62
Coastal Non-Refinery Industrial Waste	0.10	6.62
Urban Runoff	0.10	6.62
River Runoff	0.53	35.10
Atmosphere	0.18	11.92
Natural Seeps	0.12	7.95
Subtotal	0.10	
Total	1.51	

SOURCES OF OIL INPUT TO THE UNITED STATES COASTAL ZONE

There are several sources for oil entering the marine environment. These are given in Tables 1 and 2 along with the estimated annual input rate for each source. Figure 1 provides a graphical presentation of the pathways of oil input to the marine environment. Table 1 compares the estimates for the world input and those for the United States inputs. Table 2 presents the United States input in

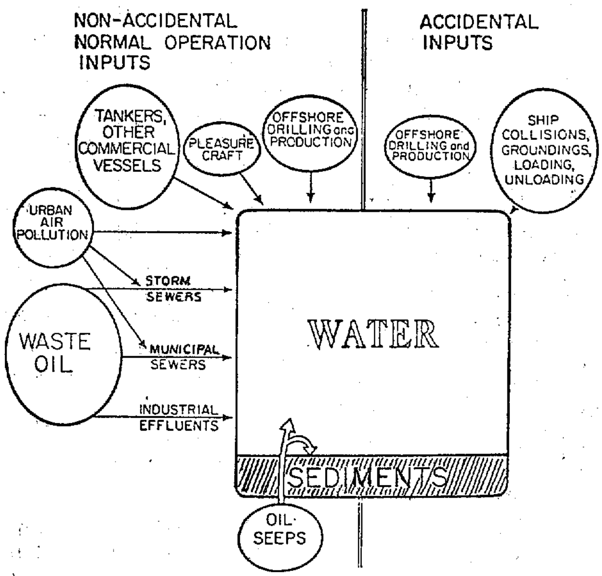

FIGURE 1.—Pathways of oil input.

terms of annual input rates and the percentage of the total input in each category.

Several important points about these tables are:

1) The world input values and some of the United States input values were taken directly from the NAS (National Academy of Sciences) report (1973, 1974). Other values for the United States input were calculated from values given in the NAS report.

2) The estimated input rates are in some cases approximations with a wide range of uncertainty. The NAS report ranked the estimates according to the degree of confidence in the value given. These rankings are given in Table 1.

3) These estimates are global or national averages. The relative importance of the various sources of oil entering the marine environment varies with geographical location and time. For example, a large well blowout would be a massive input of oil to a given location and even when averaged over a 10 year period of time would result in the offshore drilling and production accidental input category dominating inputs for that geographical location.

4) The largest inputs of oil are from normal operations and are intentional discharges. Accidents account for only 4 percent of the U.S. input and 6 percent of the world input to the marine environment.

5) Oil tanker operations account for 16 times as much oil input as offshore production for the U.S., and 20 times as much for world inputs.

When considering the oil inputs to the coastal zone, as opposed to the total marine environment, some consideration must be given to the location of the inputs from tanker operations. The largest input in tanker operations is from ballasting operations. These normally should occur at sea well away from coastal areas. How much of this input actually reaches the coastal areas is a complex function of the physical, chemical, and biological weathering and degradation of the oil and also the surface current system off the coast. My guesstimate is that very little of the total tanker discharge reaches the U.S. coast although the portion that does in the form of tar particles, tarballs, or slicks may be aesthetically unpleasing and contribute to the total impact of oil pollution on the ecological integrity of the coastal zone.

6) The atmospheric input figure given in Table 2 is the estimated U.S. input to the world oceans. The input to the coastal zone from dry fallout and rain is some unknown fraction of the value in Table 2.

7) The input from rivers and from land operations contiguous with the U.S. coastal waters is substantial and accounts for 57 percent of the total input.

8) The effect of the input from the various sources can be quite different. For example, accidental spills are point source and point in time inputs which may have immediate acute effects and long term chronic effects. Municipal or industrial effluents on the other hand may have no measurable immediate impact but may have long term chronic effects as the concentration of the petroleum chemicals builds up in the ecosystem receiving the input.

Management Decisions Suggested by the Input Data

Several important points relating to the control of oil pollution discharges are suggested by our current knowledge of oil inputs to the coastal zone.

1) The largest category of inputs is the chronic dribbling of oil into the coastal zone by industrial and municipal effluents, urban runoff, and river runoff from inland areas. Thus a substantial amount of oil will be discharged to the U.S. coastal zone regardless of whether it is transported to the coastal zone via tanker or produced by offshore wells in the U.S. coastal and continental shelf waters. Unless steps are taken to reduce it this input will increase as our oil consumption increases.

Management decisions which would have a significant effect in reducing this input are:

a. Reduce per capita oil consumption.
b. Encourage re-refining or reuse of waste oils. This would reduce inputs and help conserve a valuable natural resource.

c. Require the application and/or development of technology to reduce the amount of oil in industrial effluents, including refinery effluents. This applies both to effluents discharging directly to streams, rivers, or coastal waters and those discharging to municipal sewers.

2) Drilling and producing oil in offshore areas is safer for the total marine environment than importing equal quantities of oil because current estimates are that approximately 0.014 percent of oil produced offshore is discharged to the marine environment, whereas about 8 times as much or 0.11 percent of the oil transported by tanker is discharged to the marine environment. This assumes that oil produced offshore from a given location is piped ashore and refined or used there without subsequent transportation by sea to other locations. The statement must also be qualified in that it is assumed that the impact of accidental spills and chronic small inputs from oil tankers and from offshore production and drilling have similar effects per unit amount of oil input. Finally, this statement does not take into account the ecological damage which may result in coastal areas due to the construction and maintenance of pipelines and onshore facilities.

IDENTIFICATION OF SOURCES OF MYSTERY OIL SPILLS

Mystery oil spills for which the source is unknown account for 30 percent of the oil spills in United States waters (NAS, 1973, 1974). There are two potential means by which the source of mystery oil spills can be identified. The first method is active tagging of oil tanker cargoes, pipeline loads, and storage tank contents with microscopic spheres or special chemicals. The size of the bureaucracy necessary to ensure accurato records renders this method impractical.

The second method involves detailed chemical analysis of the spilled oils and potential sources. The chemical parameters are then compared and the best match of a potential source with the spilled oil is attempted. This technique is called "passive tagging" and makes use of the unique chemical composition of each oil to distinguish oils one from another and match oils from source and spill samples. The technique is also referred to as "fingerprinting," which is perhaps unfortunate. Many nonscientists in the field of oil pollution control have mistakenly equated "fingerprinting" in identifying mystery oil spill sources with fingerprinting in criminology. This is not the case. The former is in its infancy as a technique.

The success of passive tagging in actually proving beyond a reasonable doubt the source of a spill depends on having a complete collection of all possible sources. Then the analytical chemist applies increasingly more sophisticated analytical techniques until the parameters of one potential source match the parameters of the spill sample. However, if the actual source is not present in the sample collection incorrect identification could result. It could be that a further application of more sophisticated chemical analysis would have shown that in fact the source was not among the collection of possible sources. Passive tagging can be used to eliminate possible sources and give a probability estimate of the source.

The status of passive tagging in criminal or civil court cases involving oil pollution has yet to be extensively tested. The technique is of use in proving potential sources of a mystery oil spill were not the actual source. The technique used in conjunction with other corroborative evidence may provide sufficient evidence to identify the source of a spill. Aside from the legal aspects, passive tagging may provide some estimate of the extent and severity of oil pollution from a known source such as a refinery effluent, producing well, or accidental spill of known origin.

The scientific and technical aspects as well as limitations of passive tagging are discussed in detail by Zafiriou et al. (1973), Gruenfeld (1973), Lynch and Brown (1973), Miller (1973), and Coakley (1973).

PATHWAYS OF TRANSFER AND FATES OF OIL INPUTS TO THE MARINE ENVIRONMENT

A basic understanding of the various pathways of transfer and fate of oil inputs has been arrived at from laboratory studies, field studies, and the application of existing scientific knowledge of processes in the marine environment. These pathways and fates are diagrammed in Fig. 2. Fundamental questions which are yet to be satisfactorily answered about transfer pathways and fates are:

- What portions of oil inputs follow each of the various pathways of transfer?
- What are the rates of biochemical and chemical degradation of whole oil and components of oil during the various stages of movement through the marine environment?
- What are the final rates of removal of oil by

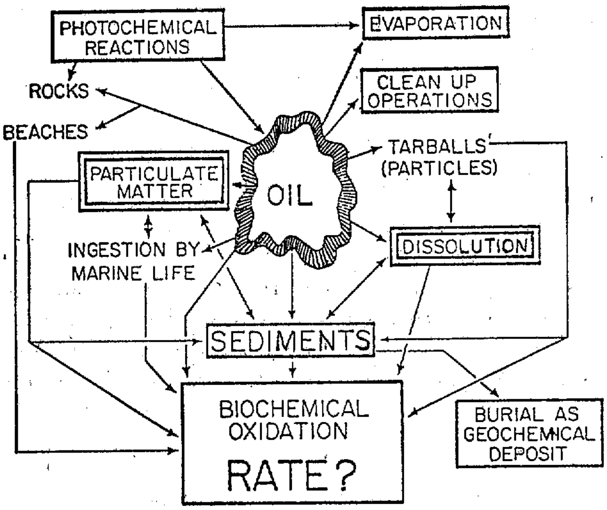

FIGURE 2.—Fate of oil inputs.

biochemical and chemical degradation, and by deep burial in sediments?

Physical-Chemical Processes

Many of the processes which act on the oil result in a fractionation of the oil and selective removal of certain components from the marine environment more rapidly than others. Lower molecular weight components of the type found in kerosene, gasoline, and in varying concentrations of crude oils and fuel oils will evaporate more rapidly than the heavier molecular weight components such as those making up the bulk of lubricating oils. The lower molecular weight components are also more soluble than the heavier molecular weight molecules. For example, several experiments (Boylan and Tripp, 1971; Frankenfeld, 1973; API, 1974) have shown that when No. 2 fuel oil is placed in contact with sea-water, the aromatic hydrocarbons of the fuel oil are dissolved or accommodated in the water to a greater extent than are the saturated hydrocarbon components of the oil.

The adsorption of oil onto or into suspended sediments and subsequent washing with water can result in fractionation of the oil with some components adhering more readily to the sediments than others (Meyers, 1972). However, this may not always occur. Mixing of a No. 2 fuel oil with sediment by wave action and turbulence resulted in essentially intact oil being incorporated into sediments (Blumer et al., 1971b).

Once oil is incorporated into sediments it may be transported to other areas by resuspension and transport of the oil polluted sediment (Straughan and Kolpack, 1971; NAS, 1973, 1974; Blumer et al., 1970). Man also plays an important role in this process by dumping oil polluted sediment from harbor dredging and sewage sludge in coastal areas such as the New York Bight (Farrington, 1974). The result of the natural or manmade processes is to spread the oil polluted sediment and thus the affected area increases even though dilution processes may ameliorate the effects somewhat.

Biodegradation of Oil

Extensive research has been aimed towards a better understanding of the biodegradation of oil and individual classes of compounds, and individual compounds found in oil (NAS, 1973, 1975; Davis, 1967; Zobell, 1969; Ahearn and Meyers, 1973). The majority of these studies are laboratory studies. There is little doubt that several species of micro-organisms, e.g. bacteria and yeasts, will completely degrade certain components of oil given the right conditions in the laboratory or in the field. It has been established that the rate of degradation will depend on many factors such as the concentrations of nitrate, phosphate, and dissolved oxygen in the water, the presence of other organic compounds, and the history of previous exposure of an area to oil inputs.

Bacteria capable of partially degrading oil have been isolated from several locations in the world's oceans. However, the rate at which the degradation of oil will proceed in the various types of coastal areas is unknown. Also questioned is the potential pathogenicity towards marine organisms for some species of bacteria which might increase in number near or in an oil spill area (NAS, 1974). Likewise, little is known about the toxicity of the chemicals produced by microbial degradation of oil. In fact, we have only rudimentary knowledge of the biochemical pathways and products of the biochemical degradation of oil (NAS, 1973, 1975; Davis, 1967; Zobell, 1969; Ahearn and Meyers, 1973).

Oil in Marine Organisms: Input, Retention, Release, Metabolism

The pathways of oil incorporation into marine organisms are outlined in the left portion of Figure 3. Oil may enter marine organisms by ingestion of contaminated food. Oil may also enter marine organisms from water across membrane surfaces such as gills.

Data collected in three independent studies sug-

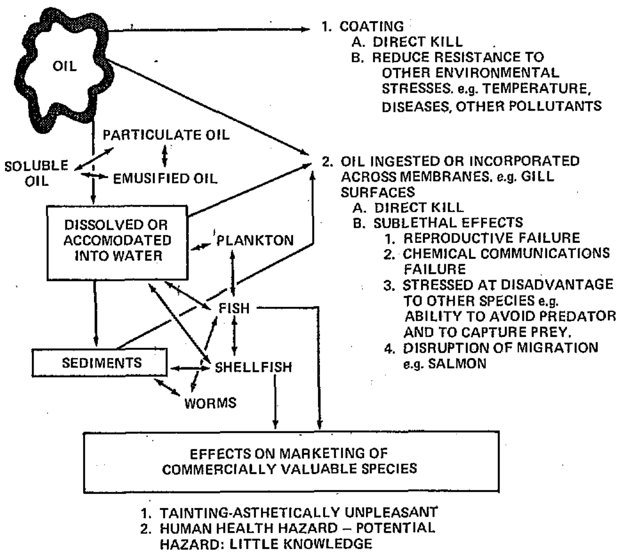

FIGURE 3.—Pathways of oil incorporation into marine life and effects on marine life.

gest that oil incorporation into shellfish and fish is reversible to some extent when the shellfish or fish are placed in clean water for a period of time (Stegeman and Teal, 1973; Lee et al., 1972 a, b; Anderson, 1973). Most, but not all, of the oil taken up from water by the shellfish was discharged within weeks to months. Indications, however, from a limited number of analyses for one experiment reveal that oysters exposed for two months to oil from an oil spill did not appreciably reduce their oil pollutant content even after 180 days in cleaner waters. The fact that this experiment gave somewhat different results than the other experiments may be a result of the heavy dosage of oil experienced by the shellfish under spill conditions.

Fish tested in the laboratory partially metabolized several different aromatic hydrocarbons of the type found in crude and fuel oils (Lee et al., 1972b). Mussels, however, did not metabolize these compounds under similar laboratory test conditions. (Lee et al., 1972a). This points to the obvious danger of extrapolating from one class or species of organism to others. Furthermore, caution should be exercised in extrapolating from the few compounds tested to other compounds in petroleum since differences in the molecular structure of compounds can have profound effects on the rates at which the compounds are metabolized, if they are metabolized at all.

The above studies provided several replicate tests of the uptake of petroleum hydrocarbons from water by marine organisms and the retention and release once these organisms are placed in clean water. Aside from the few measurements mentioned above (Blumer, 1971), there are no studies of the retention of petroleum hydrocarbons taken up under conditions of massive inputs to the organisms' habitat by oil spills. There are also no studies on the uptake, retention, and discharge of petroleum hydrocarbons via ingestion with food. The studies cited above do provide a good model for future studies of longer duration which could test the effects of years of exposure to chronic inputs of oil via uptake across membrane surfaces from water or ingested with food.

An important question for which these studies provide some insight is whether or not there is food web magnification of oil pollutants. An example of food web magnification is the process where oil pollutants of X concentration in phytoplankton would become 10X concentrated in the zooplankton which eat the phytoplankton, and 100X concentrated in the fish which eat the zooplankton. This process would occur if the zooplankton and fish, the higher members of the food web, accumulated all the pollutant they ingested and did not metabolize or discharge a portion of the pollutant. This process, if operative, would mean that many commercially valuable species of marine organisms which are higher members of the food web may concentrate petroleum pollutants to the extent that adverse effects would ensue. There is also the question of whether concentrations would reach a limit which would adversely affect the human consumer. The data collected in these and two other studies (Burns and Teal, 1971, 1973) suggest that food web magnification is not operative for some communities of marine organisms.

Application of Existing Knowledge

BIODEGRADATION OF OIL INPUTS

Investigations of the feasibility of seeding oil spills with bacteria shown to be capable of degrading oil in the laboratory have been initiated (Miget, R. J., 1973). This has been suggested as only a last resort approach by the NAS report (1974). The benefits accrued from releasing an essentially uncontrolled chain of unknown events are far outweighed by the potential hazards at this time.

Applications of existing knowledge about biodegradation of oil may find widespread use in the near future. Biodegradation of oil in industrial effluent holding ponds, tanker ballast waters either in tanks on the ships or in holding facilities on shore may be a feasible method of partially cleaning up this type of input to the marine environment while it is still concentrated at its source (NAS, 1974).

PATHWAYS OF TRANSFER AND FATE

It is known to some degree how oil pollutants move through the marine environment and where they tend to accumulate. This information facilitates surveys of the extent and damage of the oil inputs to the marine environment. It also provides input to models which attempt to predict the movement of oil spills and their severity and extent.

Another application is in the evaluation of the advantages and limitations of methods of treating or cleaning up oil spills. For example, the use of non-toxic emulsifiers (see later section on effects) or dispersants on an oil spill would result in increased dissolution of the oil and accommodation into the water column, adsorption into particulate matter, and incorporation into sediments. On the one hand this might further the biodegradation of the oil by increasing mixing of oil, nutrients, oxygen, and naturally occurring microbial populations capable of degrading the oil. On the other hand, it would spread oil throughout the water column and sediments, potentially increasing the extent and severity of the toxic effects on organisms. The incorporation of significant quantities of the oil into sediments could prolong the exposure of an area to the oil and have an adverse effect on the bottom dwelling organisms. Resuspension of the sediment and transport to other areas would increase the size of the affected area.

The use of sinking agents to remove the slick from surface waters would also result in the incorporation of the oil into sediments and thus may not be advisable for the same reasons cited in the previous paragraph. Of course, in cases where dangers from fire or extensive damage from coating of boats or beaches is the primary concern then the use of sinking or dispersing agents would be advisable.

The discussion in the preceding paragraphs underlines the point that prevention of accidental discharges is preferable to cleanup operations. Likewise, it is clear that research and development concerned with physical contamination and cleanup of oil spills should continue.

Summary

Once oil is released to the marine environment it is subjected to multiple processes and moves via many pathways through the marine environment. Research during the past few years has documented beyond any doubt that the absence of a visible oil slick in no way assures the absence of oil in the underlying waters, sediments, or organisms. Furthermore, oil incorporated into sediments may persist for years (Blumer et al., 1970). Since sediments are an integral component of their environment, this same exposure may affect the adjacent marine environment in varying degrees.

An additional important point to make regarding oil pollution of marine organisms consumed by man is that negative indications of oil pollution by taste panel tests have occurred even when the shellfish tested contained at least 2 ppm (wet weight) of oil pollutants from a No. 2 fuel oil spill as determined by chemical analysis (Blumer et al., 1971b). The chemicals responsible for the adverse taste may be metabolized or released more rapidly than the bulk of the oil pollutants in the organisms. Therefore, negative taste panel tests do not assure the absence of oil pollutants. Furthermore, there has yet to be a study to calibrate taste panel tests with seafood containing known concentrations of oil.

Recommendation

It is essential that further research be conducted on the transfer of oil pollutants into marine organisms, partitioning of the pollutants within the organisms, metabolism within the organisms, and release or discharge of oil pollutants once the organisms are no longer exposed to the oil pollutants in their habitat. This information is basic to understanding the effects of oil pollution on marine organisms, to understanding pathways of transfer and fate of oil pollutants in the marine environment, and to understanding if, when, and how oil pollutants accumulate in seafood.

MEASUREMENT OF AND CURRENT LEVELS OF OIL POLLUTION IN THE UNITED STATES COASTAL ZONE AND CONTINENTAL SHELF

Analysis of Marine Samples to Detect Petroleum Pollution

Discussions of the procedures used and the problems encountered in analyzing marine samples for quantities of oil not visible to the eye are given in several references (NAS, 1973; NAS, 1974; API, 1969, 1971, 1973; Goldberg, 1972b; Goldberg, 1972c). The discussions are of a very technical nature and are best summarized for a report of this type as follows:

1) Several cases have been reported in which petroleum hydrocarbons from accidental spills and from chronic inputs have been detected.

2) No one method of analysis will provide reliable estimates of the concentration of the entire range of

petroleum compounds. Fuel oils and crude oils are complex mixtures of compounds with wide molecular weight ranges. There has yet to be a complete analysis of a single crude oil.

3) There are marked differences between hydrocarbons biosynthesized by organisms and hydrocarbons in petroleum. The latter are very much more complex than the former and include a wide variety of compounds which have not been found in organisms in laboratory culture experiments or in areas where there is little or no petroleum pollution. However, many sources exist for small amounts of hydrocarbons in marine samples: biological processes, geochemical processes, pollution processes. Careful attention to recognizing the possible inputs from these sources is needed in order to detect man's input of petroleum pollutants. In areas where natural oil seeps occur, this problem is extremely difficult.

4) Reports of the presence or absence of petroleum pollution should be carefully evaluated to be certain that the methods of chemical analysis employed would indeed provide the information claimed to have been obtained.

Present Concentrations of Oil Pollutants in U.S. Coastal and Continental Shelf Areas

There are a limited number of measurements of oil pollutants in the water, sediment, and organisms of the United States coastal zone. Only a few locations have been sampled more than once. In addition to the lack of data, it is difficult to compare one area with the other because of the differences in methods of analysis and criteria for distinguishing oil pollutant hydrocarbons from hydrocarbons present due to biogenic or contemporary geochemical processes. Despite these restrictions the data do provide estimates of the present concentrations of oil pollutants and are given in Table 3. These data are taken mainly from the NAS Report with elimination of the data for coastal areas of other countries and for deep sea samples.

General conclusions which can be drawn from these data and the data given in the NAS Report from which they were summarized are as follows.

1) Oil pollutants have been detected in sediment, water, and organisms in areas of large oil spills.

2) Oil pollutants have also been detected in sediment, water, and organisms from areas where no large spills have occurred in the past months or years. These areas are near sources of small spills and chronic dribbling inputs.

3) No more than an estimated 300 analyses for petroleum pollutants in sediment, water, and organism samples have been reported in the literature to date exclusive of reports of visible sheens on the water.

Table 3.—Concentrations of petroleum pollutants in water, sediments, and organisms of the coastal and continental shelf areas of the United States

Water:	less than 2 μg/liter to 50 μg/liter
Sediments:	less than 1 $\mu g/g$ dry weight to 3500 $\mu g/g$ dry weight
Organisms:	less than 1 $\mu g/g$ wet weight to 230 $\mu g/g$ wet weight
Tar on Beaches:	East Coast (1969)—5 g/meter to 8 g/meter Florida, Miami Beach to West Palm Beach (1973)—avg. of 5.4 g/meter California (1961)—3 to 100 g/meter

NAS (1973, 1974), and references therein.

The fact that there are so few published measurements of the extent and severity of oil pollution in sediments and organisms in United States coastal waters probably testifies to the difficulty of making analytical measurements to detect petroleum pollution. (Goldberg, 1972a).

EFFECTS OF OIL ON THE MARINE ENVIRONMENT

Aesthetic Effects

The coating of beaches, shorelines, and recreational and commercial boats and ships by spilled oil is an obvious adverse effect. This represents a financial loss to boat owners and to the recreational and aesthetic value of a shoreline (NAS, 1974; Butler et al., 1973).

Biological Effects

TOXIC EFFECTS

Toxic effects involving the death of the organism exposed to oil may occur soon after exposure to the oil slick or to oil components transported through the water or via sediments as indicated in Figures 2 and 3 and previous discussions. Toxic effects may also occur at later dates as the concentrations of oil in the organisms increase or the oil is transported to new areas.

Toxic effects generally can be divided into two categories: effects from smothering in the oil, or effects from oil taken into the organisms or absorbed into the organisms from water or sediments. Toxic effects have been reported for spilled oil and from studies in the laboratory (NAS, 1974).

SUBLETHAL AND CHRONIC EFFECTS ON ORGANISMS

These effects do not directly result in the immediate death of the organism exposed to oil. There are numerous ways that oil can have an adverse effect on marine life without the result being immediately apparent in the form of dead plants or animals. The types of effects in this category which have been observed or suspected as being important for individual organisms are effects on:

Reproduction
Fertilization and development
Growth
Metabolism—photosynthesis and respiration
Behavior
Cells and organs

Some specific examples of the above are given below. A more detailed presentation is given in the NAS Report (1974).

1) The reduction in the intake and metabolism of phytoplankton detritus by mussels (Gilfillan, 1973)—an effect on metabolism.

2) Reduction in the rates of photosynthesis of phytoplankton cultures (Kauss et al., 1973; Parker, 1974). This is an interference with the process by which carbon dioxide is converted to food for the major part of marine life—an effect on metabolism.

3) Interference with the chemical communication between marine animals. Many marine animals communicate with one another via chemicals given off to the water, i.e. odors. Some predators are attracted to their prey by smell. One study has shown a significant adverse effect on the finding of food by a predator (Jacobson and Boylan, 1973).

Chemical communications or chemotaxis are also important to the reproduction of some animals. Male lobsters are attracted to female lobsters for reproductive purposes by a chemical released by the female. Low concentrations of chemicals resulting from oil in the water may interfere with this process.

A third area where chemical communications is important is in the area of migration to home rivers by anadromous fish for the purpose of spawning. One laboratory study has shown that oil in seawater repels salmon from entering the water of their home stream (Rice, 1973).

The significance of these studies is that they demonstrate the potential effects that low concentrations of oil in water might have if a spill or chronic release occurred at the time of year when marine animals were entering the reproductive phase. The effects on predator-prey interactions would be important throughout the year. These are effects on behavior which result in adverse effects in other functions such as reproduction and metabolism.

4) Blue mussels which were juveniles in the area of the West Falmouth oil spill at the time of the spill developed almost no eggs or sperm the next season (Blumer et al., 1971a). The development of sand dollar eggs has also been shown to be adversely affected by oil in the laboratory studies (Parker, 1974)—effects on reproduction.

5) Effects at the cellular and organ level in clams have been reported. Soft shell clams from an area near an oil spill had a higher incidence of gonadal tumors than soft shell clams from a control area (LaRoche, 1973)—effects on cells and organs and probably on reproduction.

EFFECTS ON THE COMMUNITIES OF MARINE ORGANISMS

Closely related communities of organisms may also be profoundly affected. For example, effects on marsh grasses may cause the marsh to be an unsuitable place for the crabs and mussels which live in the marsh. Effects on worms in the sediments can affect the fish which feed on the worms. Many worms also play an important part in sediment stability. Their tubes contribute to holding the sediment in place. If the worms are killed and the tubes decay the sediment may be easily eroded and the polluted sediment transported to other areas. The movement of the sediment will disturb other organisms living on the bottom even though they might not have been directly affected by the oil.

OIL SPILLS

One of the most heated controversies regarding oil pollution is that surrounding studies of the biological effects of oil inputs to the marine environment. The controversy is due in part to a seeming contradiction of the reported effects or lack of effects when comparing studies of oil spills. The contradiction arises when one does not carefully read reports and take into account two basic sets of factors for oil spill studies.

The first set of factors pertains to the oil spill itself. These factors were set forth by Straughan (1972) and have recently been restated (NAS, 1974). They vary from spill to spill and influence the effect and fate of the spilled oil. They are:

Type of oil spilled
Dose of oil in a given area
Physiography of the area of the spill

Weather conditions at the time of the spill
Biota of the area of the spill
Previous exposure of the area to oil pollution
Exposure to other pollutants
Treatment of spill, e.g. use of emulsifiers, dispersants, or sinking agents

A second set of factors influencing oil spill studies are:

1) A spill is not predictable as to its location and time. In the past, studies of spills have been of the nature of getting out into the area with the best available means at hand and studying what could be studied within the expertise of the scientists involved. In an ideal situation this would involve biologists, chemists, geochemists, geologists, meteorologists, and physical oceanographers. Such a team of scientists is rarely sitting around waiting for an oil spill to happen and as such it is difficult for them to drop everything they are doing and head out for the field or immediately begin laboratory studies.

2) The different methods used to study oil spills, the different animals or plants studied, and differences in the duration of the study vary from one spill to the next. Thus, the task of trying to compare studies from one spill to the next is a frustrating one somewhat akin to comparing measurements of distance in kilometers to measurements of distance in miles without having more than a foggy idea of the conversion factor.

The oil spill studies to date have shown that spilled oil does adversely affect some marine organisms (NAS, 1973, 1974). The effects vary in severity and duration. Complete recovery may take years and is not related to whether or not there are visible concentrations of oil present.

Laboratory Studies of Biological Effects

A comparison of laboratory studies of the effects of oil on marine organisms suffers from many of the same restrictions cited in the above section on oil spills. A variety of oils have been tested on a variety of marine organisms under a variety of laboratory conditions.

However, several studies have been conducted under conditions similar enough or conducted in the same laboratory so that the following comments can be set forth (NAS, 1973, 1974). The studies have shown, as one might expect, that concentrations of oil at which biological effects occur can vary from fuel oil to fuel oil and crude oil to crude oil when tested against one species. The studies have also shown that different species and adults and juveniles of the same species vary in their susceptibility to toxic effects when tested against the same oil.

Effects of Offshore Drilling and Production

The question of the long-term effects of offshore drilling and production on fisheries is one which has no easy answer. Certainly, the fisheries in the Gulf of Mexico have not been destroyed and are a viable sector of the economy. This experience suggests at first glance that no long-term effects have been noticed. However, for the sake of argument I propose the following scenario: Prior to offshore production in the Gulf of Mexico the fisheries there were at a very low level of productivity due to natural causes. During the past 30 years or so the fishery would have increased in productivity potential by a factor of 10. However, because of some unknown and undetected effect of the oil production the fishery only increased in yield by a factor of 2. This factor of 2 suggests by itself that the oil production had no long-term effect and may have been somewhat beneficial. However, we cannot state for certain that there was no effect, since in reality we do not know what the fishery potential would have been without the oil production. The hypothetical factor of 10 which was used for the sake of the argument might have been realized without the presence of the offshore drilling and production activities. Likewise, it may be argued on a hypothetical basis that without the offshore drilling and production rigs the fishery may have declined due to natural causes. Without knowledge of natural fluctuations in fisheries it is impossible to conclude whether or not offshore production adversely affects fisheries.

Several other factors suggest caution when using the Gulf of Mexico fisheries as an example for advocacy of drilling and production in other areas. The oil produced may have a much greater effect per unit weight than the oil produced in the Gulf of Mexico. The fisheries may be of a different type and dependent on species much more susceptible to the effects of oil. The combined effects of oil and a different environment may be more severe.

It is certain that pipelines coming onshore and support facilities on shore can have a severe effect on coastal areas if not properly managed (St. Amant, 1972).

more spectacular. It is known that offshore drilling and production discharges only a small fraction of the total oil input to the marine environment. It is also known that the major input of oil to the marine environment is the result of the chronic dribbling losses which accompany present methods of using oil.

Pathways of Transfer and Fates of Oil Inputs to the Marine Environment

It has been demonstrated once again that the cliche "out of sight, out of mind" should not apply to environmental problems. The disappearance of an oil slick does not mean that the oil has disappeared from the marine environment. Oil inputs move by a variety of pathways through the marine environment and are affected by many processes. The ultimate fates of oil discharged to the marine environment are chemical or biochemical degradation, and/or burial at depth in sediments. Our knowledge is mostly of the qualitative nature of these movements and processes. Extensive quantitative estimates of rates of movement and rates or processes affecting oil inputs are still lacking.

Effects of Oil on the Marine Environment

The known or suspected effects are diagrammed in Fig. 3. The aesthetic effects are obvious. The immediate toxic effects are also apparent from studies of accidental oil spills. Subtle long-range chronic and sublethal effects are known in a few cases and suspected in many others. Effects can be at the level of cells and organs, whole organisms, or communities of organisms.

The chronic long-term effects of offshore drilling and production are largely guessed at or suspected. The long-term environmental hazards or the long-term safety of offshore drilling and production are both unproven.

Human health hazards resulting from eating oil contaminated seafood are suspected but not yet proven.

APPLICATIONS OF OUR PRESENT KNOWLEDGE

1) It appears that the major sources of oil input to the marine environment have been defined. It is clear that the only hope of a significant reduction in the major oil input to the marine environment in the immediate future is a reduction in the total consumption of oil. Since this does not seem likely, programs to reduce the dribbling of oil into the marine environment should be instituted. Reuse or re-refining of waste oils is an example of a program which would help to reduce inputs and conserve a valuable resource.

2) A reduction in ship accidents might be accomplished by better traffic and safety regulations. Reduction in the amount of oil spilled in an accident might be accomplished by the construction of false bottom tankers. The use of the false bottoms as segregated ballast tanks would also reduce the amount of oil entering the marine environment from tanker ballasting operations. A detailed discussion of this subject is given in the Final Environmental Impact Statement, Maritime Administration Tanker Construction Program (NTIS, 1973).

3) Offshore drilling and production with its attendant risks appears to be safer in the long run for the marine environment as a whole than importing an equal quantity of oil. This argument assumes that the oil produced offshore is piped ashore and not transported elsewhere.

If we assume that we will continue to consume oil and even increase consumption, then we should proceed with offshore drilling and production as soon as the problems with coastal land use plans, jurisdiction over offshore operations, and socioeconomic problems are resolved.

The arguments about the long-term effects of offshore drilling and production involve such large segments of the marine environment that satisfactory answers will only be obtained by conducting the experiment. That is, conduct the offshore drilling and production in such a manner as to ensure close monitoring and control. Given close monitoring and accompanying research in the laboratory and the field there is a good chance of averting an ecological catastrophe before it occurs. This does not mean that all adverse effects will be detected, but rather that any effects which escape the monitoring and control processes will be small and acceptable in return for the benefit of the oil resource utilization.

It should be emphasized the sacrifice of the long-term potential productivity of the offshore fisheries resource is not advocated. In fact, this would be a primary consideration of any research and monitoring program.

4) The knowledge of pathways of transfer and fate of oil inputs is sufficient to provide an evaluation of some methods of combating oil slicks. In addition, the movement of oil slicks and oil in the marine environment is sufficiently documented to be of some use in making first approximation models of the fate of oil spills (MIT, 1973).

EFFECTS OF REFINERY EFFLUENTS AND OIL DISCHARGED IN EFFLUENTS FROM MUNICIPAL AND STORM SEWERS

Investigations of the effects of oil refinery effluents have shown that release of effluents in sheltered tidal waters killed nearby marsh plants (Baker, 1971). Refinery effluents released to waters exposed to rapid flushing characteristics had little noticeable effect (Baker, 1973). However, only a few segments of the community of marine life were investigated.

No studies of the effects of oil discharged by sewage and storm sewer effluents have been conducted. It would be difficult to unravel the effects of the oil from the effects of the other chemicals in these effluents.

SYNERGISTIC EFFECTS

There is concern that oil pollutants and other pollutants such as PCBs will act in concert such that their combined effects are more severe than predicted from the sum of their effects when acting individually. No reports of such studies have been published to date.

Human Health Considerations

The most significant potential human health hazard is the consumption of seafood contaminated with oil. There are at present no standards for deciding if a particular concentration of oil in seafood represents a human health hazard.

A very emotional controversy centers around the carcinogenic potential of oil contamination of seafood (Anon., 1974). The NAS Report (1974) states—"That the amount of one carcinogen, benzopyrene, entering the oceans from oil is small compared to the amount released into the total global environment from other sources." The report further states "Our knowledge of the properties of all the constituents of petroleum is not complete and therefore there might be some dangerous materials present in petroleum that are still unidentified."

The manner in which the NAS report (1974) approached the problem of carcinogens in seafood could be misleading to the public and decision makers. The report places emphasis on the point that the consumption of oil contaminated seafood by the average consumer would expose the consumer to a very small amount of carcinogens relative to the amount he is exposed to from other sources such as air pollution. I submit that the problem of consumption of carcinogens in oil contaminated seafood should be treated and explained as the problem of radionuclides in seafood is treated and explained. Average inputs or average consumptions should not be used. Rather, care must be taken to ensure that all segments of the population are protected (Bowen, 1974).

An acceptable level for oil in seafood should not be set simply because the average New York resident is exposed to 200 times or more carcinogens from other sources. Rather, the acceptable risk level, if there is one, should take into account the Maine shellfisherman who eats far more shellfish and may be exposed to far less carcinogen input from other sources.

Summary

Documented studies of the effects of oil on marine organisms are limited in number. The data available show that different oils have different degrees of effects on organisms. Effects range from immediate lethality to subtle long-range effects. The effects of a single oil vary from species to species and within a species vary from adult to juvenile.

Our knowledge of the subtle sublethal and chronic effects of oil is severely limited. Data from a few studies provide a basis for concern. Certainly, further studies are warranted based on the data collected on these problems.

It is impossible to decide at present whether or not offshore fisheries suffer long-term adverse effects from offshore drilling and production. The data needed is not available and will be extremely difficult to obtain.

SUMMARY OF MAJOR AREAS OF PROGRESS TO DATE

The last five years have provided significant overall advancement in our knowledge of the input, fate, and effects of oil in coastal and continental shelf areas. There has also been a significant increase in the awareness of oil pollution in the public, governmental, and industry sectors. New laws and regulations have resulted as well as research and development of new technology to reduce oil pollution.

Inputs

Our knowledge of the sources of oil entering the marine environment is now at the stage where we can estimate their relative importance and begin studies to better quantify the inputs. It is known that accidental inputs are a small fraction of the total input even though accidental spills are much

5) We have a fair understanding of the immediate toxic effects of oil. We also have a suspicion and in some cases rudimentary knowledge of the subtle sublethal and long-term chronic effects of oil on marine life. The foundation has been laid for future studies to detail the concentration levels and environmental conditions at which oil will affect marine life.

6) It is known that seafood consumed by man can be contaminated by oil. This should stimulate research to set acceptable levels for human consumption. In this regard, it is essential that the worse possible case be considered for the consumption of oil-contaminated seafood. The experience in protecting seafood consumers from radionuclides should be used as a guide (Bowen, 1974). Use of an average rate of consumption of oil contaminated seafood to arrive at a decision whether there is a serious public health hazard may expose a segment of the population to unwarranted risk.

RESEARCH AND MONITORING NEEDS

Any study of marine environmental quality problems is based on current knowledge of biological, physical, chemical, and geological processes in the marine environment. Continued and increased funding of research towards understanding these basic processes in the marine environment is absolutely essential for short-term and long-term protection and upgrading of marine environmental quality.

Research into general aspects of oil pollution problems or in specific areas should be conducted in a manner which is scientifically sound and flexible enough to pursue interesting and relevant problems as they develop. Available funds should be primarily funneled to scientists via research grants. This mechanism is preferable to the Request for Proposal (RFP) route which seems to be gaining favor in government environmental research management. Research grants written by scientists and reviewed by their peers have a better chance of producing useful scientific information than the RFPs issued in the field of oil pollution research.

More extensive measurement of the extent and severity of oil pollution in United States waters is needed. Measurements should be made in a manner which will provide answers as to pathways of transfer, rates of transfer, processes of transfer, and fates of oil inputs in the marine environment.

Measurements in areas of offshore production, oil ports, and refinery locations as well as control areas remote from these locations are needed to detail man-induced and natural fluctuations. Monitoring should make use of sample archiving as a means of reducing costs. Samples would be collected from several locations within study areas and control areas. However, only samples from key representative locations would be analyzed to determine if adverse effects and/or increased petroleum contamination were present. If such increases or effects were detected, then the entire sample set for that season or year could be removed from archives and analyzed to determine the geographical extent and severity of the effect or increase.

Cost of Oil Pollution Research

The sophisticated types of investigations which are needed to understand the inputs, fates, and effects of oil pollution in the marine environment require substantial funds. For example, the costs for collecting, analyzing and reporting data on the level of petroleum pollutants in samples of water, sediments, and organisms from four sampling sites in an offshore production area and two control areas would be about $180,000 per year if sampling were conducted four times a year. If the costs of biological analyses, geological and physical oceanographic studies are added and the total multiplied by monitoring of three potential offshore drilling and production locations on the Atlantic Continental Shelf, then the cost would be about $2.5 million per year. These estimates are based on current costs of obtaining such data in research programs and may be reduced somewhat by concentration of activities and reduction in cost per analysis because of the large volume of analyses needed.

SPECIFIC RECOMMENDATIONS FOR RESEARCH AND MONITORING

Inputs

1) Reliable identification, quantification, and monitoring of variability of inputs.

2) Development and application of better remote monitoring capabilities.

Measurements

1) Development and/or application of reliable methods for detecting and quantifying oil pollutants in water, sediment, and organisms.

2) Application of these methods in conjunction with investigations of biological effects, transfer processes, and fates of oil inputs.

3) Wider geographical coverage and time series measurements of oil pollutants in the marine environment.

Transfer and Fates of Oil Pollutants

1) Development of models for predicting movement and fate of oil spills and chronic oil inputs. This should be undertaken for harbor areas handling large volumes of oil cargoes, offshore drilling and production areas, oil storage areas, and pipeline routes.

2) Research to better document the rates of biodegradation of oil in situ in the marine environment. This includes research to identify pathways of metabolism or chemical reaction and the effects of the products of these processes.

3) Research to better understand the uptake, retention, metabolism and release of oil pollutants from marine organisms. This includes further research as to whether or not food web magnification of oil pollutants is operative and, if so, when and where.

4) Research to quantify the rates and processes affecting movement of oil through the marine environment.

Effects

1) Toxic effects measurements.

2) Long-term chronic, lethal, and sublethal effects measurements both in the laboratory and in situ.

3) Research on human health aspects of oil pollution of seafood. Needs to be resolved as soon as possible. This is a very emotional issue and one which places federal, regional, state, and local health authorities in a quandry. They have no guidelines to use in deciding when to restrict or allow consumption.

4) All studies of effects should be accompanied by reliable controls and quantitative measurements.

Oil Spill Studies

I have read several final or draft reports of oil spill studies conducted by contractors to the Environmental Protection Agency. Most reports were of limited value. The study teams were environmental divisions of industrial companies or small environmental companies. The teams did not have or obtain the necessary expertise to conduct a very competent study. This could be excused up to two years ago because the areas of study and difficulty associated with the oil spill studies were not widely known to either contracting officers in the Environmental Protection Agency nor to the regional study teams. There is now no excuse for throwing away any more money on studies of the quality of those conducted in the past.

A mechanism for ensuring quality of oil spill studies and at the same time involving competent scientists in oil spill studies is as follows.

Provide funding to a few key laboratories for laboratory and field studies on the effect and fate of new refinery discharges and offshore production. This would ensure that a good solid nucleus of research scientists and associated facilities would be actively engaged in oil pollution research. When an oil spill occurred which, in the judgement of the Environmental Protection Agency project officers and the research scientists, was of interest from the point of view of gaining some knowledge about the fate and effects of oil spills then a study team could be formed by the expansion of the existing research team.

This plan does away with the need for "instantaneous" emergence of a research team at the time an oil spill study is desirable.

Laboratory and Field Studies

The understanding of inputs, transfers, effects, and fates of oil inputs which is needed for effective management of oil inputs and protection of the marine environment will only be obtained by both laboratory and field studies. For example, field measurements will provide an estimate of the existing concentration levels of oil. Laboratory bioassays can then proceed to determine if these have a long-term effect. Conversely, laboratory studies can provide an estimate of the acceptable concentration level of oil in the marine environment. Field studies can establish how close the current concentration levels are to the acceptable concentration level and project when closer control of inputs will be needed in a given area. Furthermore, it is impossible to reconstruct an entire natural ecosystem in a laboratory. Field studies are essential to investigate effects on large segments of ecosystems or entire ecosystems.

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CONSEQUENCES OF OIL POLLUTION IN THE ESTUARINE ENVIRONMENT OF THE GULF OF MEXICO

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ABSTRACT

Incidences of oil pollution have been recorded for over 200 years, but only within the last 10 years has public attention been focused on the problem. Initially, the concern was for the aesthetic and acute effects; but attention has now been largely redirected toward low-level chronic effects, especially those posing a human health hazard. Other areas of increasing concern are the potential synergistic action of oil in conjunction with other pollutants and the long-term chronic effects of oil on the ecosystem. Data available in the literature have served to identify the potential problems, but definition and resolution must await additional data. More emphasis must be placed on translating scientific data into information utilizable for making estuarine management decisions.

INTRODUCTION

The estuaries, unlike true marine or freshwater habitats, continually vary in salinity, and chemical composition and concentration (Christmas, 1973; Odum, et al., 1974). It has been shown that these factors influence the toxicity of oil (Gilfillan, 1973; Tagatz, 1961). Further complicating an assessment of oil pollution on the estuarine ecosystem is the fact that some biological species inhabit the estuary only at certain times of the year (e.g., shrimp), while other permanent inhabitants (e.g., oysters) have different life stages present at different times of the year. Coupling these characteristics with the interaction of other pollutants, the complexity of the problem is clearly illustrated.

While all estuarine areas are under constant threat of damage from oil pollution, particularly in terms of the acute effects caused by major disasters, the estuarine areas of the gulf coast are uniquely susceptible to low-level, long-term, chronic pollution because of the shallowness of the coastal waters and the comparatively small tidal action. Considering the fact that the gulf receives 60 percent of the drainage of the contiguous United States (Geraghty, et al., 1973) and many years are required for recycling the waters of the gulf, the precarious position of the gulf coast estuaries is evident.

Crude oil is not a chemical compound but consists of thousands of chemically identifiable compounds and no two crude oils have the same composition. Fortunately, or unfortunately as the case may be, the addition of an extremely small amount of oil to water will cause a visible sheen. Fortunately, this characteristic alone makes it extremely easy to detect oil, even to an unskilled observer, and it is interesting to note that the Federal Sheen Regulation takes advantage of this characteristic. Unfortunately, there are water-soluble constituents in crude oil, and it has been shown that these compounds can have a deleterious effect on some biological species (Gilfillan, 1973; Nuzzi, 1973; Brocksen and Bailey, 1973; Katz, 1973). Therefore, the lack of a visible sheen does not insure that there is no damage to the ecosystem resulting from oil pollution.

Ever since 1754 there have been reports on oil pollution (Nelson-Smith, 1973). The Torrey Canyon incident in 1967 served to focus worldwide attention on the problem of oil pollution, and there has been an almost overwhelming number of papers on oil pollution since that time. While it has been major oil spills as the Torrey Canyon and Santa Barbara that have been responsible for the intense interest in the impact of oil pollution on the environment, it is ironical to note that these major spills account for only a fractional amount of the oil added to the environment each year. By and large, the huge quantities of oil that find their way into the estuaries of the gulf coast have gone unnoticed by the public. Only recently the public has been aroused to the potential health hazards of low-level oil pollution. For example, a 1973 report (Anonymous, 1973; Hites and Biemann, 1972) on the presence of a variety of organics (including some from oil) in the Charles River must have caused some public concern, particularly in view of the speculation on the possibility of biological magnification of potentially toxic compounds. Even more recently, press releases have resulted from the EPA report on the New Orleans water supply, linking pollutants contained in drinking water derived from the Mississippi River to cancer (Anonymous, 1974a; Anonymous, 1974b). Mercifully, the articles did not speculate on the potential biological accumulation of these compounds in seafood. This problem will be addressed in more detail later in this report.

The widely circulated article by columnist Jack Anderson emphasized the possible connection between oil pollution and the almost hysterically feared disease, cancer (Anderson, 1974). It is not the purpose of this report to delve into the moral and/or legal aspects of this disclosure (Seltzer, 1974), but merely to illustrate vividly one of the major areas in need of immediate scientific research. In the eyes of many people, the fouling of beaches and the death of large numbers of birds after a major oil spill shrink to insignificance in comparison to the threat of ingesting cancer-causing compounds in seafood or drinking water.

Ecological disaster is ecological disaster, no more, no less. The causative agent is inconsequential in this respect, and pesticides and mercury already have been brought to the public attention. Oil now is being emphasized as the perpetrator of ecological doom. The facts of the case are that the fundamental principles of nature which govern the behavioral, physiological and genetic phenomena are the same irrespective of the toxicant involved. The problem really becomes more one of quantitation and study of the causative agent rather than one of identifying and studying some strange new biological principles. Admittedly, there are some differences in specifics, but by utilizing existing knowledge, the cost and time required to obtain the data necessary for making estuarine management decisions can be significantly reduced.

There are many facets to the problems of oil pollution in the estuarine environment which will not be addressed in this report. The quantities and sources of oil input and its fate in the environment is the subject of another paper for this report. Methods of treating oil wastes, cleanup procedures after accidental spills and the impact of oil drilling and production operations are not considered in this report.

The purpose of this report is to (1) comment on the usefulness of available information on oil pollution from a standpoint of estuarine management; (2) highlight some of the developing areas of concern; and (3) make concrete recommendations concerning future research needs.

VALUE OF CURRENT INFORMATION FOR ESTUARINE MANAGEMENT

From a standpoint of the acute effects of oil, there are numerous reports on laboratory studies and field investigations of accidental spills (Blackman, 1973; Cimberg, et al., 1973; Chan, 1973; Straughan and Abbott, 1970; Holme, 1969; Holmes, 1969; Mackin, 1973; Jones, et al., 1969; Stebbings, 1970; Anonymous, 1956; Spooner, 1969; Straughan, 1969; Burns and Teal, 1971; Valéry, 1968; North, 1967; Mackin and Sparks, 1962; Hay, 1974; Battelle Memorial Institute, 1967; Blumer, et al., 1970). These accounts have documented the fact that crude oils and petroleum products will kill a wide variety of biological species. While these data may be helpful in determining or predicting the extent of damage to a given area, the amounts of oil required to produce acute effects are sufficiently large that they are completely unacceptable from an aesthetic standpoint alone. Obviously then the information is of little value in formulating water quality criteria, effluent standards, and so forth.

The evidence is mounting that even very low levels of oil can cause a myriad of long-range, chronic effects and may even pose a serious human health hazard (Blumer, 1969; Tarzwell, 1970; Nelson-Smith, 1970). This has caused a considerable amount of concern in the public sector.

Laboratory studies are generally carried out under controlled conditions and are useful in identifying and defining potential problems. The data from this type of investigation also are valuable in designing field experiments, but it is hazardous to project laboratory findings into usable information from a decision-making standpoint. In the case of oil pollution, laboratory studies have identified a multiplicity of problems that may occur in the estuaries but have not completely defined these problems.

Data from field investigations on the long-range effects from oil spills are of very limited value for a variety of reasons, including: (1) the lack of adequate ecological baseline data for the area; (2) the impact of cleanup operations; (3) the lack of established control areas required for comparative purposes; (4) the inability to deploy sufficiently large teams of competent experts within the required time frame; and (5) the nonuniformity of methodology and techniques employed by investigators. As a result of these defects, there is an understandable difference of opinion among investigators as to the long-range effects from these oil spills. While differences of opinion are healthy and are to be expected, in some cases existing data are manipulated to prove a given position on the damage caused by oil pollution rather than objectively interpreting the data as it exists (Mackin, 1973). Surely, many of these seemingly conflicting points of view will be resolved in the foreseeable future.

To date the available data have offered very little information of direct value in making estuarine management decisions, but have identified some of the areas of developing concern. Following is a brief summary of the information available in four of the more important areas of concern.

Potentially Carcinogenic Compounds in Oil

The potential health hazard that could arise from the biological magnification of carcinogenic compounds from oil has been mentioned previously. Highlights from the scientific literature will help to put the problem in better perspective and serve to illustrate some of the complexities involved. In the first place there are reports relating constituents of oil to cancers in a number of fish species (Battelle Memorial Institute, 1967; Tarzwell, 1970). Additionally, there are reports that potentially carcinogenic hydrocarbons are widespread in the marine environment, even in plants and animals taken from areas considerably distant from any known oil pollution (Nelson-Smith, 1973; ZoBell, 1971; Newman and Olson, 1974). This raises the question as to the source of the compounds involved, and it has been pointed out that many carcinogenic hydrocarbons are produced by various species of bacteria, algae and higher plants (ZoBell, 1971; Borneff, et al., 1968). Laboratory studies have demonstrated that microorganisms are capable of degrading these carcinogenic compounds (ZoBell, 1971).

The fundamental principle of preferential utilization of nutrients by bacteria is well established, and it has been shown that this occurs in the case of oil (Phillips, 1972); furthermore, many of the most resistant compounds pose the greatest potential health hazard. Therefore, the basic issue involved is what really happens in the environment. The reports on the persistence of many of these carcinogenic compounds tend to support the view that their biodegradation in nature is a slow process.

Bioaccumulation of many pesticides, particularly the chlorinated hydrocarbons, has received considerable attention by the scientific community. There is reason to believe that the same phenomenon would be observed with components of oil, and, indeed, there are reports to this effect (Nelson-Smith, 1973; ZoBell, 1971).

Differences of opinion exist in the scientific community on the possible links between oil pollution and cancer. There is agreement that considerably more research is needed before a true assessment can be made.

These problems are particularly germane to the gulf coast for reasons cited earlier: the continual input of large volumes of pollutants, the long residence time, and the utilization of seafood resources from this region.

To date, the data available only have served to identify this most important problem, but have not made available the kinds of information required for making estuarine management decisions.

Oil as a Concentrator of Other Toxicants

Potentially, the role of oil as a concentrator of other toxic materials may outweigh its other effects in terms of contributing to the human health problem. For example, one study has shown that the concentration of mercury in oil was 4,000 and 300,000 times greater than it was in sediments and water, respectively, taken from the same area (Walker and Colwell, 1974). Further, increased oil content of sediment samples was associated with increases in zinc, chromium, lead, copper, nickel, cadmium, and mercury (Walker and Colwell, 1974).

The problem of biological magnification of pesticides and its potential significance to the health of the ecosystem and to human health has already been mentioned. In this respect, a recent report on the action of oil slicks as concentrators adds a new dimension to the impact of oil on the ecosystem. Aldrin, dieldrin, DDT, and possibly lindane, heptachlor expoxide, and chlordane were identified from samples taken from surface slicks, but were not in detectable amounts in the seawater samples from the same area (Seba and Corcoran, 1969).

The implications of the concentrating characteristics of oil for both toxic heavy metals and pesticides are obvious.

Effect of Environmental Factors on Oil Pollution

It is a well established fact that the physical, chemical, and biological structure of a system has a significant effect on the action of a given toxicant—oil is no exception. For example, the toxicity of oil increases as the oxygen concentration (Battelle Memorial Institute, 1967; Kontogiannis and Barnett, 1973) or salinity (Rice, 1973) decreases.

The point to be made here is that there is an urgent need to understand the action of oil under different environmental conditions, since the facts indicate clearly that while a given level of oil may be ecologically tolerable under one set of circumstances, it could be disastrous under other conditions.

Long-term Impact of Oil on the Ecosystem

From the literature, a multiplicity of responses to oil would be expected and have, indeed, been reported. Such things as diminishing growth rates in phytoplankton (Mommaerts-Billiet, 1973), physiological stress and degeneration of gill tissue and muscle in oysters (Clark, et al., 1974), changing respiratory rates in salmon and striped bass (Brocksen and Bailey, 1973), and altering behavioral patterns (Rice, 1973; Ecological Research Series, 1973; Boylan and Tripp, 1971) are but a few of the vast array of oil pollution effects.

To gain some concept of the potentially catastrophic effects of oil pollution on the ecosystem, it is necessary only to draw an analogy to the work on pesticides.

1) Gross changes are not required to bring about untimely extinction of a species.

2) A slight lowering of the primary productivity by reducing photosynthetic capability would reduce dramatically the productivity of the entire ocean.

3) Changes in migratory habits, feeding areas, or spawning grounds would jeopardize the current fishing industry.

4) Slight changes in reproduction ritual could upset the balance of the ecosystem.

All biology is geared to survival of the species and is reflected in a buildup of resistance to pollutants or other adverse conditions that may well exact penalties in other species—including man. For example, it has been shown that mosquitofish that have acquired a resistance to insecticides will accumulate these compounds to such high levels that they are fatal to higher members of the food chain (e.g., birds and snakes) (Ferguson, 1967).

RECOMMENDATIONS FOR THE FUTURE

When one considers the fantastic complexities of the estuarine ecosystem with its highly complicated interactions, the literally thousands of compounds present in crude oil, the impact of environmental conditions on the effects of oil on the system, the multiplicity of responses elicited from the presence of oil on the various organisms, and the impact of other pollutants on the whole situation, it would appear that a complete understanding of the impact of oil on the estuarine environment is impossible both scientifically and economically.

The immensity of the overall problem makes it evident that a considerable effort must be put forth in establishing the areas of priority and coordinating individual research. Otherwise, as past experience has demonstrated, there will be a proliferation of small programs resulting in information that is difficult, if not impossible, to use effectively for managing the estuaries. The urgency of the situation cannot be overemphasized.

In terms of priorities, emphasis should be placed on gaining a better understanding of the long-term chronic effects of oil pollution rather than studying the acute effects resulting from major accidents. As indicated earlier, the acute effects are obvious and, by definition, are of a short duration, while the long-term chronic effects may remain for many years and may not manifest themselves until irreparable damage to the area has been done. More specifically, the following problem areas are in urgent need of extensive research, conducted in such a fashion that the data are utilizable for making estuarine management decisions directed toward maintaining our estuaries in a healthy viable state.

Areas of Research

1) *Problems directly related to human health (particularly cancer)*. Projects in this category should generate data on the fate of carcinogens from oil in the environment, assess the role of oil in contributing carcinogens to the environment, establish the likely pathways of biological magnification to seafoods for human consumption, establish standards in regard to maximum levels allowable in the environments from which human seafoods are harvested, and establish methods and standards for allowable concentrations of various constituents in seafoods for human consumption. A minor effort also should be put forth to examine ways of reclaiming polluted areas and to develop additional methods of preventing pollution in regard to the carcinogens in oil.

2. *Oil as a concentrator of other toxic pollutants*. With the widespread presence of many kinds of agricultural (pesticides) and industrial (heavy metals) pollutants already present in the environment, knowledge of the interaction of these materials with oil is of vital concern. Numerous laboratory studies have been conducted on the impact of various pollutants on a wide array of biological specimens but,

essentially, no studies have been made on these materials in the presence of oil.

The specific questions to be answered are: (1) Does oil concentrate these other pollutants from the environment, and (2) Does oil enhance the uptake of other pollutants by the biota. The major thrust should be investigations in the field and/or in pilot plant systems as described below. To a lesser degree, some laboratory investigations should be conducted to determine if oil and these other pollutants act independently, synergistically, or antagonistically.

A closer coordination with other research programs could decrease substantially the cost of these studies by a merging of efforts.

3. *Long-term chronic effects of oil on the ecosystem.* The list of problems in this category is rather long and priorities vary considerably from investigator to investigator. Emphasis should be placed on the more long-lasting, potentially disrupting influences that may last for generations, rather than the shorter-term effects for which there is evidence of quick recovery and which are thus concerned primarily with a single generation.

Furthermore, the data should be generated in such a form as to be useful in estuarine management decisions and, as a general rule, should include both laboratory and field experimentation. Some of the more important questions needing attention are: (1) Does oil cause any genetic changes; (2) Does oil alter reproductive processes; (3) Does oil increase susceptibility to disease or increase the virulence and/or numbers of pathogens; and (4) Does oil interfere significantly with vital behavioral characteristics. Of necessity, most of these studies will require multi-year efforts.

It is probable that much valuable information could be obtained by the long-term monitoring of the environment after a catastrophic spill. It is highly important that an immediate post-spill evaluation be made by a coordinated team of competent scientists; this evaluation could serve as a yardstick both for immediate effect and for long-term recovery.

4. *Effect of environmental conditions on oil toxicity.* Because of the constantly changing conditions in the estuary, information concerned with the impact of these various parameters on oil pollution is required in order to manage the estuaries effectively. The effects of salinity and temperatures are but two of the parameters that can change significantly the impact of oil on the ecosystem. The major value of this information is in determining the time and conditions wherein the estuaries are most vulnerable to oil; it will be useful in establishing operational procedures within the estuaries.

Types of Research Efforts Required

To formulate effectively the overall kind of program required to meet the needs, three general types of investigations are needed.

1. *Laboratory investigations.* Many of the problems can be handled effectively by individual researchers working in individual laboratories, but there should be some overall coordination of the specific objectives to be accomplished, though not necessarily the procedures to be employed. In other words, these problems could best be answered by a grant type program, where the emphasis is on the creativity and expertise of the individual scientist. These results will serve as vital inputs to larger programs conducted under more natural conditions. Their value cannot be minimized in terms of their contribution to the effective long-range management of the estuaries.

2. *Pilot plant investigations.* Conceptually, the use of pilot plant systems is routine in the engineering profession. These systems are necessary to test the validity of laboratory findings on a more realistic basis.

For oil pollution studies, the pilot plant could take the form of either an artificially constructed impoundment in the field or a natural area that can be regulated and controlled. Under these circumstances a physically and biologically manageable system with a minimal amount of perturbations from outside forces can be studied. The system would more closely approximate the natural environment and increase the reliability of predictions based on the results of the investigations.

There seems to be little doubt that investigations of this nature have the greatest chance of generating useful estuarine management data in the shortest time frame. These efforts must involve large teams of competent scientists working in a well-planned coordinated program. Unquestionably, large amounts of money will be required, but the cost effectiveness will be an order of magnitude greater than if smaller programs are conducted simply on the basis of multiple use of control data alone. For example, the analyses for oil in the water column and sediments are time-consuming and expensive, and if different investigators are working in different locations or on different organisms, each would require the same analyses.

3. *Investigations of accidental oil spills.* As indicated previously, two of the major reasons for the limited value of the data derived from investigations of accidental oil spills are (a) lack of adequate pre-spill baseline data, and (b) the inability to deploy the

desired scientific staff in time to maximize the value of the data obtained. While this report is directed toward the impact of oil on the estuarine environment, it should be realized that a thorough understanding of the ecosystem is necessary for the most useful management of this valuable resource. This understanding also is of vital importance in determining the impact of pollutants other than oil (e.g., pesticides, thermal pollution, and so on). Economics dictates that only representative areas can be subjected to these kinds of investigations, but years will be required before meaningful data are obtained.

In this connection, it should be pointed out that the institutions of higher learning are an excellent source of expertise and resources for this type of undertaking. While having the scientific guidance of senior scientific personnel, much of the work can be handled by graduate research assistants. In this fashion, not only will the scientific aspects of the program be met economically, but also this plan offers the obvious spin off value of contributing to the badly-needed reservoir of trained environmental scientists for the future. Pursuing this line of reasoning further, there is every reason to believe that many of these same people could become a functional part of the environmental response teams that are needed to investigate accidents. Since the total environmental team already would be in contact and familiar with the ecosystem involved, the problems of an effective response would be minimized. In other words, these university environmental teams will be most valuable to the government and/or industrially contracted response teams in terms of formulating the specifics of the investigation, supplying some of the scientific direction, and making available many kinds of highly specialized equipment and facilities. There is every reason to believe that this kind of interdisciplinary, multi-institutional program can be mounted successfully in an economically practicable and scientifically meaningful fashion.

SUMMARY

If the amount of oil entering the environment each year were reduced to zero, the problems associated with oil pollution would disappear with time. While this may be desirable idealistically, it is certainly unrealistic. More emphasis on preventing accidents, improved technology in containing and cleaning up accidental spills, and an accelerated effort to reduce the input of oil from all sources will reduce significantly the danger from oil pollution. The literature clearly indicates that a substantial effort must be put forth immediately if we are to maintain and/or reclaim our estuaries as a healthy viable resource.

One cannot help but be impressed, in a negative way, by the lack of usefulness of the data on oil pollution in terms of estuarine management. To date, the major value of the research has been in identifying the potential long-range problems that could result from oil pollution of the estuaries. The fact that an ecological catastrophe has not occurred is fortunate and an increased research effort on oil pollution should reduce significantly the probability of such an event. The translation of scientific data into information utilizable for making estuarine management decisions must be accelerated and more emphasis must be placed on determining the costs (both monetary and ecological) as well as the benefits of the various solutions to the oil pollution problems.

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SOLID WASTE DISPOSAL AND ITS RELATIONSHIP TO ESTUARINE POLLUTION

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ABSTRACT

The general relationship of solid waste to estuarine pollution is described. Current major impact of solid waste on estuarine pollution comes from fills, legal and illegal, where leachates contain pollutants including pesticides, heavy metals, and oxygen-demanding materials. Most coastal states have regulated against the further use of estuarine areas for the disposal of solid wastes. It is recommended that the Federal government establish a data bank to determine where the various kinds of waste materials originate and where they are disposed. Long-range solutions to the danger of estuarine pollution by solid waste materials lie in reduction of the quantity of solid wastes generated and in large-scale recycling efforts.

INTRODUCTION

Each year the average person in the United States uses 17,500 pounds of fuel (for warming offices and houses, running automobiles and trains, firing factory boilers, and many other tasks), 23,000 pounds of construction and other non-metallic materials, 6,800 pounds of metallic ores, and almost 6,000 pounds of agricultural materials (Morton, 1974). The annual per capita consumption in the United States, then, is over 50,000 pounds, or nearly 150 pounds per person per day. Since "consumption" really means one-time (usually short-term) use, this quantity of material becomes a per capita solid waste disposal problem. This contrasts rather dramatically with the "tip of the iceberg" of solid wastes visible to most of us who generally think of solid wastes as household garbage and rubbish. But household garbage and rubbish are just one of the 11 major streams of solid waste produced in this country, and account for a minute percentage of the 150 pounds per person per day total waste production.

The 11 major streams of waste may be lumped into the three broad categories of municipal waste, agricultural waste, and industrial waste. Municipal waste includes residential, commercial, and demolition wastes; agricultural waste includes animal manures and waste from fruit and nut crops and from field and row crops; industrial waste includes waste from food processing, manufacturing, and lumbering, as well as chemicals and petroleum.

On a per capita basis, municipal wastes account for about 3 to 5 pounds, agricultural wastes, about 15 pounds, and industrial wastes, nearly 130 pounds per day.

Since nearly 80 million people in the United States live within 50 miles of an ocean coastline, while another 30 million live within 50 miles of the Great Lakes and the St. Lawrence River (U.S. Department of Commerce, 1973), the use of estuarine areas for waste disposal is an important consideration because these have historically been favorite solid waste disposal sites for municipal and industrial wastes. Agricultural wastes have generally been left on fields, burned, or allowed to wash into water courses. Fortunately, as will be shown later, most coastal states have now prohibited the use of estuarine areas for waste disposal. So while filling of estuarine areas is still going on, principally in San Francisco Bay and Hackensack Meadows in New Jersey, no extensive new filling of estuarine areas with solid waste appears to be taking place.

CURRENT DISPOSAL METHODS

The four primary methods of solid waste disposal are, in order of decreasing usage, landfill, resource recovery, incineration, and ocean disposal. Since estuarine areas have in the past been favorite sites for "reclamation" by filling them with solid wastes, this disposal method has had a primary impact on them. Therefore, as resource recovery and incineration become more prevalent, less pressure exists to fill estuaries with garbage. Of course, much solid waste is illegally dumped in estuarine areas.

Landfill is by far the most prevalent method of disposal in use today, with about 90 percent of municipal waste going there (Feibusch, 1970). Unfortunately, most landfills still do not qualify as "sanitary" landfills as these are defined by the American Society of Civil Engineers (ASCE). A sanitary landfill according to the ASCE is "a method of disposing of refuse on land without creating nuisance or hazards to public health . . . (volume) and to cover it with a layer of dirt at the conclusion of each day's operation . . ."

Properly developed sanitary landfills create useful land for park and recreation facilities. On the other hand, the ecological disruption caused by landfills, particularly in marshland or wetland areas, is a major negative environmental factor.

Significant amounts of waste (particularly industrial wastes) are being reused. The salvage industry today probably does an annual volume in excess of $10 billion. However, most materials now being salvaged are the homogeneous remains of manufacturing processes that are free of contaminants and can therefore be directly reused. Recovery of materials from municipal wastes is currently receiving a great deal of emphasis from planners in the waste management industry. In later sections of this report, we will discuss what efforts the States of Massachusetts and Connecticut are currently making in implementing statewide resource recovery plans.

Probably the major constraints to increased salvage and reclamation efforts are the absence of sustained demand for salvageable material and the incentives to use them. In any case, energy considerations are now forcing all waste management planners to reconsider resource recovery as a major factor in solid waste management.

The best available data indicate that incineration accounts for about 8 percent of the solid waste disposed in the United States. Many communities have recently renewed their interest in incineration in light of the predicted energy shortage. Modern incinerators are said to be 90 percent efficient in terms of residual waste. That is, for each 100 tons of combustible material burned, 10 tons remain to be disposed. Of course, the basic law of physics stating that matter cannot be destroyed is still valid, so the 90 tons of material burned are discharged either into the air or into sewers. The problem of non-combustible materials also remains. Studies in Los Angeles County indicate an overall incinerator efficiency of 48 percent with respect to the average raw refuse composition collected (including bulky materials and non-combustibles).

Less than 10 million tons of solid wastes are disposed of annually into the oceans off the continental United States. In addition, at least 53 million tons of dredging spoils are being dumped into the ocean (Smith, 1971). The question of dredging spoils disposal is currently the subject of a $30 million study by the U.S. Army Corps of Engineers under its national Dredged Material Research Program and will not be further discussed here.

REVIEW OF COASTAL STATES' SOLID WASTE MANAGEMENT EFFORTS

In order to provide an up-to-date review of the status of solid waste management efforts in the individual states, a telephone survey of the 20 coastal states was made between October 30, 1974, and November 11, 1974. In each case, contact was made with a senior official in state government responsible for solid waste regulation and management. Table 1 summarizes information obtained from this survey.

Eighteen of the 20 states surveyed have assumed primary jurisdiction for solid waste management and regulation. Only California and Washington have total local control. Actual situations in Texas and Louisiana reveal effective local control, but South Carolina under present procedures cannot exercise effective state control. Seventeen of the 20 states surveyed have adopted solid waste management legislation since 1970, indicating at least a recognition of state responsibility in the solid waste management field.

Two states, Massachusetts and Connecticut, are proceeding to implement statewide resource recovery plans, while two other states, Delaware and California, are working with demonstrations that may have significant results. Data concerning the location of solid waste fills in estuarine areas were not readily available, although the problem seems confined to the states of Maryland, North Carolina, South Carolina, Florida, Texas, and California. In Louisiana, a state with many estuarine areas, the population in the five parishes where most of the estuaries are located is quite small. It is encouraging to note that only one or two states allow new fills for solid waste in estuarine areas, and that ocean dumping appears to be practiced only in New York and New Jersey.

PROBLEMS OF SOLID WASTE LANDFILLS IN ESTUARINE AREAS

Landfilling of solid wastes in estuarine areas presents a twofold problem. First, it causes a reduction in the limited acreage of marshland and wetland

Table 1.

State	Population (Millions)	Jurisdiction	Date of Enabling Legislation	Status of Resource Recovery Efforts	Number of Existing Fills in Estuarine Areas	New Estuarine Fills Allowed	Ocean Dumping	Acres of Estuarine Area (f) (Thousands)
Maine	1.01	P*	12/73	?	2	No	No	39.4
New Hampshire	.76	P	'72	?	?	No	No	12.4
Massachusetts	5.76	P	4/71	P.I***	1	No	No	207.0
Rhode Island	.96	P	'74	?	1	No	No	94.7
Connecticut	3.07	P	'71	P.I.	?	No	No	31.6
New York	18.35	P	9/73	?	?	No	Yes	376.6
New Jersey	7.31	P	'70	?	1	No	Yes	778.4
Delaware	.56	P	7/73	Demo†	None	No	No	395.5
Maryland	4.01	P	'70	?	15(c)	No	No	1406.1
Virginia	4.72	P	4/71	?	1	No	No	1670.0
North Carolina	5.16	P	'69	?	20	No	?	2206.6
South Carolina	2.63	P(d)	9/71	?	30±	Yes	?	427.9
Georgia	4.66	P	'72	?	None	No	No	170.8
Florida	7.03	P	7/74	?	?	No	?	1051.2
Alabama	3.49	P	'69	?	None	No	?	530.0
Mississippi	2.25	P	'74	?	None	No	No	251.2
Louisiana	3.69	P(a)	?	?	?	?	?	3545.1
Texas	11.43	P(b)	'69	?	Many(e)	No	?	1344.0
California	20.29	L**	1/73	Demo†	31	No	?	522.1
Oregon	2.14	P	5/71	?	1	No	No	57.0
Washington	3.44	L	'72	?	?	No	?	193.8
	111.77							

(a) State must use parish district attorney to prosecute. Since district attorneys are also parish legal advisors, they do not prosecute.
(b) Counties may assume control by adopting solid waste permit system. Only 4 of 254 counties have done so.
(c) Small facilities on Eastern Shore serving total of 20,000 people.
(d) Can be overruled by any professional engineer-prepared plan.
(e) Mostly small sites.
(f) Presented by Dr. Stanley A. Cain, Assistant Secretary of Interior, in testimony to the Subcommittee on Fisheries and Wildlife Conservation.
* Primary state jurisdiction.
** Local control.
*** Statewide plan implementation.
† Demonstration project.

remaining in this country, and secondly, it creates the danger of polluting vast areas outside of the fills themselves through contamination of leachates when water percolates through solid waste. A recent article in Nation's Cities (Weddle, 1974) suggests that dumps, both old and new, may be a potential threat to many groundwater supplies. Certainly if this is the case, estuarine areas in which dumps are located are also affected. Leachate generation in this country, according to the Environmental Protection Agency (EPA), may approach some 46 billion gallons annually. A significant percentage of this leachate enters estuarine areas where it introduces toxicants, heavy metals, and pesticides, and produces oxygen depletion.

The Third National Congress on Waste Technology and Resource Recovery, sponsored jointly by the EPA and the National Solid Waste Management Association, in San Francisco November 14 and 15, 1974, may provide the impetus needed to tackle the problem of leachate contamination on a national level.

SOLUTIONS—LESS WASTE, MORE EFFECTIVE RECOVERY

As suggested in the previous section, much progress has been made in reducing the negative effect of solid waste pollution on estuarine areas. However, ultimately the answers to pollution problems from solid waste of estuarine areas do not lie solely in more rigid regulations or more detailed guidelines. They lie also in producing less waste and in doing a more effective job of recovering fractions of the waste that we do produce.

Management plans for solid waste can no longer be based on least first cost alone. They must be based on the concept of least net cost, taking into account a direct monetary outlay, the cost of environmental pollution, and the value of resources conserved. The "hierarchy of choices" concept for solid waste management is suggested as a systematic approach to solid waste management, minimizing resource waste and maximizing resource recovery. Under the hierarchy of choices, the best waste management choice is carried to its logical and practical limit, and then the next best choice is applied to what remains. There are six choices, and the waste that is finally left over for burial is a small fraction of the original amount. The hierarchy of choices is as follows:

Source Reduction

This involves modifying some products and materials and stopping the manufacture of others. It would require that serious consideration be given in the design stage to ultimate disposal of any manufactured product. Superfluous packaging materials are obvious candidates for this approach. Action by state and federal legislatures, vigorous support from local agencies, and strong citizen support would be necessary to reduce the production of waste.

Reuse Without Processing

Some glass, metal, and paper articles are suitable for direct reuse. More consideration must be given to encouraging a collection system that separates these materials at the point of origin. The controversial Oregon "bottle law" is an example of state efforts toward reuse of resources.

Reuse With Processing

Materials not suitable for direct reuse, but which can be successfully blended with virgin materials at time of processing (glass, aluminum, paper, tin cans), can be separated at transfer points and made available to industry as raw materials.

Conversion

The organic part of the remaining material can be decomposed into a soil-like humus by composting or pyrolyzed by applying heat in the absence of oxygen. Composted materials would be applied to the land to produce stable topsoil.

Change of State

The combustible material that still remains can be incinerated, producing gas and energy. Incinerators need to be located where there is a demand for steam in the immediate vicinity.

Burial

Some materials will always need to be disposed in landfills. But these landfills should be located where development plans call for changes in existing ground elevations. Since the material that remains after having been processed through the previous five steps in the hierarchy is inert and earthlike, the problem of landfill stability will be greatly reduced.

The hierarchy of choices concept will have to be employed in a flexible way, since local conditions may obviate some and favor others, but if it is employed in a systems engineering sense, it can be appropriate under any given set of circumstances.

ENERGY CONSIDERATIONS

As a nation, we are currently involved in a massive drive to find alternate sources of energy, having recently discovered that a dependence of foreign oil could have devastating effects on our way of life. To a large extent, the whole problem of solid waste management has become affected by the "energy crunch." As with all such crash efforts, it will take several years before we realize that the crucial problem is not how much energy we generate but what our real net energy needs are. Thus it may be that according to the hierarchy of choices concept in the previous section, organic municipal and agricultural wastes can be more useful when converted and added to the land as a soil amendment rather than being burned. Much work needs to be done to minimize the need for energy in solid waste management. The institution of transfer stations where waste materials are transferred from small to large vehicles is one of the more obvious energy-saving devices being considered by many communities.

PROGRAMS WITH PROMISE

As we have mentioned, the States of Connecticut and Massachusetts have taken a leading role in developing statewide solid waste management plans that emphasize resource recovery. The Connecticut plan (Anon., 1974b) proposes 10 regional solid waste recycling centers to be constructed by the Connecticut Resource Recovery Authority (CRRA), a non-profit, tax-exempt public service corporation. Private firms in the resource recovery industry will contract with CRRA to design, construct, and operate the 10 regional centers. Firms have been selected to build plants at Bridgeport and Berlin, Conn. The plants are scheduled to go into operation at the rate of one per year. The first two plants will recover fuel, ferrous metals, aluminum, and glass.

The State of Massachusetts, with a somewhat less ambitious program than that of Connecticut, has approved the development of the first resource recovery facility in Lawrence to serve the regional needs of the Merrimack Valley. This plant is to be built, operated, and owned by private entrepreneurs. Recovery of metals and fuel is envisioned (Anon., 1974a).

The city of St. Louis and Union Electric Company are jointly undertaking a significant program for utilization of refuse for energy production. Shredded air-sorted refuse and coal have been used for some time now on a test basis to generate electricity at the Meramec Power Plant of Union Electric Company in St. Louis. Extensive tests have not revealed any serious problems of air pollution, although modification of the refuse-coal composition and close mixture control were found necessary. Union Electric Company and the city are currently developing a $70 million program for five to seven transfer stations throughout St. Louis, making it possible to use all of that city's combustible solid waste for energy.

The Delaware Reclamation Project proposes to use 500 tons of solid waste and 230 tons of sewage sludge per day and recycle them into marketable materials. This demonstration is essentially to prove the viability of an aerobic digester to produce humus. Other machinery would produce solid fuel, carbon, fuel gas, ferrous and non-ferrous metals, paper, and glass cullet. The plant will be designed with enough capacity to handle all the wastes in Newcastle County (Wilmington).

In the San Francisco Bay Area, a group of 15 local agencies joined together in 1972 to test the feasibility of using composted organic solid waste in the low-lying areas of the Sacramento-San Joaquin Delta for levee stabilization, land building, and agriculture. These local agencies, calling themselves The Bay-Delta Resource Recovery Action Committee, took a first step not only in solving the problem of solid waste (including sewage sludge) in the bay area but also in forming the regional institution framework necessary to do this. This effort was entirely voluntary without coercion from either state or federal agencies.

Briefly, the plan called for strategically located processing transfer stations where directly recoverable materials would be removed. The balance would be shredded and air classified, with the light fraction being mixed with sewage sludge and composted, while the heavy fraction would undergo further recovery processing. The composted fraction would then be shipped by barge to the Sacramento-San Joaquin Delta, where it would be placed behind dikes for support and to raise the land levels, which have been dropping steadily for many years. The composted material would be used to stabilize dikes and to serve as a growing medium for agricultural products. A pilot demonstration lasting three years and using 200 tons of composted material per day has been proposed. To date, the California legislature has appropriated $2.3 million toward the demonstration. The local agencies are currently negotiating with federal representatives for matching funds.

THE FEDERAL ROLE

Current Federal authority in the field of solid waste management as it affects estuarine areas is held by the U.S. Army Corps of Engineers under the Rivers and Harbors Act of 1899. The Corps, under the same act, issues permits for dredging and filling in navigable waters and may deny these permits based on fish, wildlife, and water quality consideration (Anon., 1974c).

The EPA's Solid Waste Management Program has no regulatory authority. Its present role is confined to establishing broad national policies, administering research and development programs, encouraging state and area-wide solid waste management planning, and providing technical assistance.

Many of the concepts proposed in the hierarchy of choices for sound solid waste management and resource recovery are embodied in legislation currently pending before various committees of Congress. The Resource Conservation Energy Recovery Act of 1974 is the most comprehensive bill currently being considered. It addresses freight rate discrimination for recycled products, source reduction efforts, hazardous waste disposal standards, long-range state solid waste management planning, and grant and loan programs for large-scale energy recovery and resource conservation demonstrations as well as full-scale plants.

Committees of the House of Representatives are discussing legislation for tax credits to recycled products manufacturers and rapid amortization proposals for recycling equipment. Both of these pieces of legislation would have a major beneficial effect on reducing the quantity of solid waste that might be destined for estuarine areas.

New legislative proposals are urgently needed that would require the EPA to establish and maintain a data bank of waste materials generated and disposed. No one today has even a general idea as to how much and what kind of material we are throwing away, where it is being thrown, and what damage it is causing. The information gathering effort required to develop this data bank is very large. However, intelligent long-range planning by both industry and regulators will be impossible until better information is available.

SUMMARY AND CONCLUSION

Each of us in this very affluent country consumes on the average 150 pounds of raw material every day. Since nearly half of us live within 50 miles of coastlines having estuaries, estuaries offer convenient dumping grounds for our leftovers. Fortunately, most coastal states have recognized the ecological importance of estuarine areas and have prohibited their filling with solid waste. So while some filling of estuarine areas is still going on, not many new fills will be started.

Concerns for raw material and energy shortages are likely to have a positive influence on resource recovery and conservation efforts. This will help to reduce the pressure on filling estuaries since less waste will be generated.

Most states have assumed regulatory control over solid waste disposal and appear to have established on-going enforcement programs to prevent estuarine pollution. Massachusetts and Connecticut are embarking on ambitious statewide resource recovery programs, while several demonstration projects with great potential are being initiated elsewhere.

A systems engineering approach is urgently needed to measure the least net cost of solid waste management programs, taking into account cost of pollution prevented and resources conserved. The hierarchy of choices concept is a useful tool in selecting waste management programs. In the hierarchy, source reduction (i.e., not making the product in the first place) is the ideal waste management solution, while throwing it away is the worst.

It is to be hoped that the federal role in the solid waste management field will soon be expanded with the provisions embodied in the proposed Resource Conservation and Energy Recovery Act of 1974 becoming law.

In general, it can be said that much improvement has taken place in the solid waste management field in the past few years, but a great deal more needs to be done before the threat of pollution of estuarine areas from solid waste is eliminated.

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IMPACT OF CHLORINATION PROCESSES ON MARINE ECOSYSTEMS

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ABSTRACT

The use of chlorine as a disinfectant and antifouling agent is reviewed. Chemical reactions of chlorine in aquatic environments are discussed, with particular emphasis on the formation of halogenated organic constituents in freshwater and marine systems. Studies of the effect of chlorinated sewage effluents and cooling water from generating stations on marine organisms and ecosystems are summarized.

INTRODUCTION

Chlorine gas has seen industrial use since 1800 as a bleaching agent and has become one of the most versatile chemicals known. In freshwater it is well known as a disinfectant for drinking and recreational water, biocide for slime and fouling control, and treater of municipal wastes for pathogen control. In these applications, vast quantities of chlorine are used, and find their way through society's effluents to natural ecosystems. The toxicity desired in disinfection and biocide applications can continue with non-desirable effects to wildlife and their ecosystems. Recent findings of halogenated organics traceable in drinking water in 80 cities, underscore the need for responsible assessment of the management and effects of our chlorination processes, and the environmental costs incurred.

The State of Maryland is often used by planners as a minimodel for the United States. In the case of rate of chlorine use, some of the most accurate statistics exist for Maryland. Furthermore, resulting chlorination constituents from Maryland mostly drain into the Chesapeake Bay. An inventory of chlorine discharge from Maryland alone into the Chesapeake Bay, assuming no degradation, results in the statistic of 27 million pounds per year of chlorine from municipal treatment plants and 2.2 million pounds per year from power generation facilities. It would appear to the casual observer that without the action of degradation processes, these amounts would soon sterilize the bay. It is calculated (but still to be confirmed experimentally) that 1 percent of these totals may become halogenated organic compounds possibly persisting in marine ecosystems. Twenty-three other states border marine ecosystems where some form or another of chlorine discharge currently persists in one manner or another.

The purpose of this paper is to compile the scarce data presently available for chlorine effects upon aquatic life of estuarine and marine ecosystems. The chemistry of chlorine is briefly reviewed to point out some of the unique features of chlorination in marine waters. Although some data exists on effects of residual chlorine and a limited number of byproducts upon specific organisms, virtually no information exists on transport processes, persistence, bioaccumulation, and fate of halogenated compounds from chlorination processes.

CHEMISTRY OF CHLORINE

Chlorine is presently manufactured by a variety of methods, including:

the electrolysis of brine,

$$2NaCl + 2H_2O \xrightarrow{\text{electric current}} 2NaOH + Cl_2 + H_2$$

the salt process,

$$3NaCl + 4HNO_3 \rightarrow 3NaNO_3 + Cl_2 + NOCl + 2H_2O$$

and the hydrochloric acid oxidation process,

$$4HCl + O_2 \xrightarrow{450\text{–}650^\circ C} 2Cl_2 + 2H_2O.$$

Chlorine in Freshwater Systems

Chlorine gas dissolves rapidly in water and hydrolyses,

$$Cl_2 + H_2O \rightleftharpoons HOCl + H^+ + Cl^-.$$

This hydrolysis is nearly complete and only when the pH is below 3.0, or the chlorine concentration over 1000 mg/l is there any measurable quantity of molecular chlorine present. The oxidizing capacity of chlorine is retained in the hydrolysis product, hypochlorous acid. Hypochlorous acid dissociates to form,

$$HOCl \rightleftharpoons H^+ + ClO^-.$$

This reaction is pH dependent. For a neutral pH (7.0) at 20°C, the equilibrium is approximately 75 percent HOCl and 25 percent ClO^-. For a pH of 8.0, the reverse is true with approximately 25 percent HOCl and 75 percent ClO^- (Sawyer and McCarty, 1969).

The addition of hypochlorite salts to water forms hypochlorite ions followed by hypochlorous acid,

$$Ca(ClO)_2 = Ca^{++} + 2\,ClO^-,$$

and

$$H^+ + ClO^- \rightleftharpoons HOCl.$$

If ammonia or organic amines are present in the water, they will react with hypochlorous acid to form chloramines,

$$NH_3 + HOCl = NH_2Cl + H_2O.$$

Like the ionization of hypochlorous acid to $H^+ + ClO^-$, the reaction rate between ammonia and hypochlorous acid is pH dependent, occurring most rapidly in solutions with a pH of 8.3. This reaction is also dependent upon temperature and the ratio of ammonia to hypochlorous acid.

Monochloramines react with hypochlorous acid to form di- and trichloramines,

$$NH_2Cl + HOCl = NHCl_2 + H_2O,$$

and

$$2NH_2Cl + HOCl = NCl_3 + H_2O.$$

Low pH favors a shift in equilibrium toward the formation of di- and trichloramines. Fair et al. (1948) determined that at pH 5.0, the ratio was 16 percent monochloramine and 84 percent dichloramine. For a pH of 8.0, the ratio was 85 percent monochloramine and 15 percent dichloramine. Trichloramine is found in significant quantities only at pH values of less than 4 (McKee and Wolf, 1963).

Ingols et al. (1953) determined that hypochlorous acid and monochloramine in freshwater will react with various organic constituents. Some of these reactions resulted in the formation of organic monochloramines although none were persistent, Table 1.

Table 1.—Summary of reactions of chlorine with organic compounds in freshwater (modified from Ingols et al. 1953)

Organic Substrate	Hypochlorous Acid	Monochloramine
Alanine	Pyruvic acid	Organic monochloramine
Cysteine	RSO_3H	RSSR
Glycylglycine	Oxidative	----------
Glycylglycylglycine	Hydrolysis and deaminization	Terminal organic monochloramine
Tyrosine	Ketone	Organic monochloramine
Hemin	Violent change	Irreversible addition or oxidation

The formation of chlorinated organic compounds during chlorination of sewage effluents and power plant cooling waters has recently been documented (Jolley, 1973; Jolley et al. 1975). Isotopic ^{36}Cl tracers and high-resolution anion-exchange chromatography were used to separate over 50 chlorine containing constituents from chlorinated secondary effluents. Fifteen of these were tentatively identified and quantified, Table 2.

Table 2.—Tentative identifications and concentrations of chlorine containing constituents from chlorinated sewage effluents (modified from Jolley, 1973)

Identification	Conc. of Organic compound ug/L
5-Chlorouracil	4.3
5-Chlorouridine	1.7
8-Chlorocaffeine	1.7
6-Chloroguanine	0.9
8-Chloroxanthine	1.5
2-Chlorobenzoic acid	0.26
5-Chlorosalicylic acid	0.24
4-Chloromandelic acid	1.1
2-Chlorophenol	1.7
4-Chlorophenylacetic acid	0.38
4-Chlorobenzoic acid	0.62
4-Chlorophenol	0.69
4-Chlororesorcinol	1.2
3-Chloro-4-hydroxybenzoic acid	1.3
4-Chloro-3-methyl phenol	1.5

Chlorine in Marine Systems

Major sources of chlorine contamination in the marine environment are related to postchlorination of secondary sewage effluents with outfalls located on coastal and estuarine waters, and chlorination of seawater used for cooling of thermal electric generating plants (White, 1972, 1973; Markowski, 1959).

The addition of chlorine to seawater results in a complex series of chemical reactions; the most obvious one frees bromine,

$$Cl_2 + 2Br^- = 2Cl^- + Br_2.$$

This reaction goes to completion and is the basis for the manufacture of bromine from seawater (Lewis, 1966).

The industrial extraction of bromine from seawater requires that the pH be reduced below 3.0, so that molecular chlorine can release molecular bromine. The hydrolysis products from adding chlorine to seawater, HOCl and ClO^-, will also release bromine from the bromide ion in the form of hypobromous acid and hypobromite ion,

$$ClO^- + Br^- = BrO^- + Cl^-,$$

and

$$BrO^- + H^+ \rightleftarrows HOBr.$$

Houghton (1946) has also suggested that chlorination of water containing free ammonia and bromine may result in the formation of bromamines. Johanneson (1958) added chlorinated water to a sodium-ammonium salts solution buffered to pH 8.3. This resulted in the formation of monobromamine and some monochloramine. The addition of sodium hypochlorite solution produced mostly monochloramine. The hypochlorite in solution apparently reacts with both the bromine and ammonia,

$$ClO^- + Br^- = BrO^- + Cl^-,$$

and

$$ClO^- + NH_3 = NH_2Cl + OH^-.$$

Injection of chlorine gas may result in localized acidity, favoring the first reaction above, which is rapid at pH values of less than 8.0. The second reaction is favored when chlorine is added as sodium hypochlorite since there is no accompanying reduction in the normal pH of 8.0–8.3.

When ammonia is present in seawater, it will react with hypobromous acid to form monobromamine. Monobromamine in turn will react with hypobromite ion to form dibromamine,

$$NH_3 + HOBr = NH_2Br + H_2O,$$

and

$$NH_2Br + BrO^- = NHBr_2 + OH^-.$$

In addition, monobromamine at near neutral pH will form ammonium bromide which dissociates into ammonium ion and free bromine (Johanneson, 1960).

$$NH_2Br + H^+ \rightleftarrows NH_3Br^+$$

and

$$NH_3Br^+ \rightleftarrows NH_3 + Br^+.$$

Block and Helz (1975) have prepared a reaction series model to illustrate the theoretical degradation processes occurring after the addition of chlorine to natural, saline waters, Figure 1. Compounds in each successive level can give rise to ones on a lower level. In general, compounds occurring on lower levels will not contribute to the formation of those in the levels above.

The reaction occurring between levels I and II is a result of chlorine decay from a diatomic gas to hypochlorous acid, hypochlorite ions, and sodium hypochlorite. As pointed out by Moore (1951) and Lewis (1966), this reaction occurs rapidly and goes to completion within seconds after the addition of chlorine. The inclusion of sodium hypochlorite

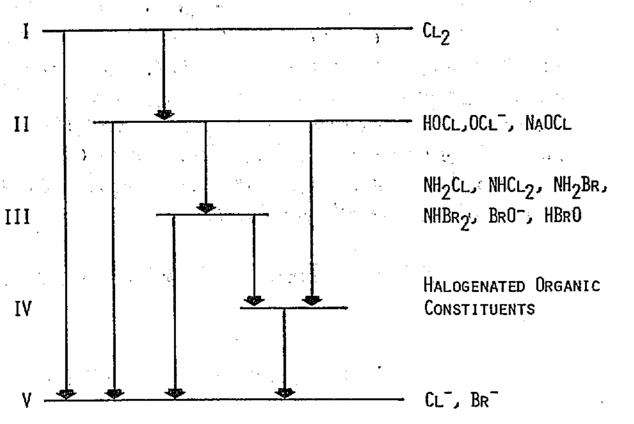

FIGURE 1.—Degradation processes for chlorine in saline waters (modified from Block and Helz, in preparation).

within level II is based on the results of work by Sugum and Helz (1976).

The chemical composition and abundance of products formed from level II to level III is a function of physical and chemical parameters of the water, including but not limited to temperature, pH, ammonia, and bromine, available as reaction components. In seawater it is possible that the predominant species would be bromamines, especially if NH_4^+ ions are less abundant than Br^- ions.

Level IV includes halogenated organic constituents which may be formed by level II or level III species, including chloramines, hypobromite and bromamines. The stable end products in level V occur through a diverse group of mechanisms taking place in steps I–IV.

Charge balance results in one atom of Cl passing from level I to level V to each atom passing from level I to level II. Reduction of hypochlorite by Br^- or Fe^{2+} and Mn^{2+} may release Cl^- from level II to level V. Movement of Cl^- from level III to level V can also occur in a number of ways; the most obvious, suggested by Laubusch (1971) involves the destruction of chloramines when the OCl^-/NH_4^+ ratio is large.

Some of the chlorinated organics identified by Jolley (1973) are persistent and the decay from level IV to level V is probably a slow process, relative to decay from levels I through III to level V.

TOXICITY OF CHLORINE IN ESTUARINE ENVIRONMENTS

The relative toxicity of chlorine in water is related to the amount and proportions of free and residual chlorine. Several investigators have found that free chlorine is generally more toxic to freshwater organisms than chloramines (Douderoff and Katz, 1950; Merkens, 1958), even though the toxicity of the various forms of chlorine was of the same order of magnitude. Rosenberger (1971) and Basch and Truchan (1973), found that dichloramine was more toxic than monochloramine in freshwater. A comprehensive review paper by Brungs (1973) summarizes the toxic effects of residual chlorine on freshwater aquatic organisms.

In seawater, Holland et al. (1960) determined that dichloramine is apparently more toxic than monochloramine and that the chloramines were more toxic than free chlorine. These findings may reflect the complex chlorine-bromine reaction kinetics suggested by Johanneson (1958, 1960) and Lewis (1966).

Chlorine Toxicity to Marine Phytoplankton

The effects of chlorination and thermal pollution on phytoplankton productivity have been investigated in some detail, Table 3. Carpenter et al. (1972) observed an 83 percent decrease in the productivity of phytoplankton passed through the cooling system of a nuclear generating plant on Long Island Sound.

Intake water was chlorinated at a rate of 1.2 mg/l with a residual of 0.4 mg/l measured at the discharge. Addition of 0.1 mg/l chlorine at the intake with non-detectable residuals at the outfall decreased productivity by 79 percent. Essentially no decreases in productivity were observed when phytoplankton passed through the cooling system without addition of chlorine. Hirayama and Hirano (1970) measured the effect of chlorination on the photosynthetic activity of *Skeletonema costatum* and found that cells were killed when subjected to 1.5 to 2.3 mg/l chlorine for 5 and 10 minutes.

Gentile (1972, 1973 unpublished data, Environmental Research Laboratory, Narragansett) observed a 55 percent decrease in the ATP content of marine phytoplankton exposed to 0.32 mg/l residual chlorine for two minutes and a 77 percent decrease after 45 minutes of exposure to chlorine concentrations as low as 0.01 mg/l. A 50 percent depression in the growth rates of 10 species of marine phytoplankton exposed to chlorine concentrations ranging from 0.075 to 0.25 mg/l for 24 hours was also measured.

Morgan and Stross (1969) used photosynthetic rates to evaluate the response of estuarine phytoplankton passed through the cooling system of a steam electric power station on the Patuxent River, Md. The photosynthetic rate increased with an 8°C rise in temperature when ambient water temperatures were 16°C or less. Inhibition occurred when ambient temperatures were above 20°C. In a related study, conducted at the same site, Hamilton et al. (1970) measured a 91 percent decrease in primary productivity during intermittent chlorination.

Chlorine Toxicity to Invertebrates

Muchmore and Epel (1973) investigated the effects of chlorination of wastewater on fertilization in marine invertebrates, Table 4. Unchlorinated sewage (from the Pacific Grove, Calif.) was a weak inhibitor of fertilization in the sea urchin, *Strongylocentrotus purpuratus*. Exposure of gametes of the

Table 3.—Summary of toxic effects of chlorinated wastes and water on marine phytoplankton

Species	Toxicant	Measured Residual Chlorine mg/l	Duration of Test	Effect(s)	Reference
Phytoplankton	Cl_2 injection	0.05–0.40	12 hrs + 4 hrs incubation	50–98% loss of productivity	Carpenter et al. (1972)
Chlamydomona sp.	Hypochlorite solution	0.69–12.9	5 min	Reduced growth rate	Hirayama and Hirano (1970)
Skeletonema costatum		0.18–2.4	5 min	None up to 0.29 mg/l; greater amts. inhibited growth	
Phytoplankton	Hypochlorite solution	0.32 0.01 0.075–0.25	2 min 45 min 24 hrs	55% decrease in ATP 77% decrease in ATP 50% decrease in growth	Gentile et al. (1972, 1973)
Phytoplankton	Cl_2 injection	----------	15 min	91% reduction in photosynthesis	Hamilton et al. (1970)

Table 4.—Summary of toxic effects of chlorinated wastes and water on marine invertebrates

Species	Toxicant	Measured Residual Chlorine mg/l	Duration of Test	Effect(s)	Reference
Strongylocentrus purpuratus (gametes)	Chlorinated sewage effluents	0.02 0.11	5 min 5 min	None 100% inhibition of fert.	Muchmore and Epel (1973)
Urechis caupo (gametes)		0.2 1.0	5 min 5 min	22% inhibition of fert. 100% inhibition of fert.	
Phragmatopoma californica (sperm)		0.2 1.0	5 min 5 min	22% loss of motility 86% loss of motility	
Ostrea edulis	Residual chlorine	10.0	48 min + 10 C	None	Waugh (1964)
Elminius modestus		2.0 5.0	10 min 3 min	Death and inhibited growth None	
Balanus sp. Acartia tonsi	Cl_2 injection	2.5 2.5	5 min 5 min	80% mortality 90% mortality	McLean (1972, 1973)
Melita nitida Palaemonetes pugio		2.5 2.5	5 min 5 min	Near 100% mortality 96 hrs after exposure	
Bimaria franciscana		4.5	4 days	None	
Anemones	Residual chlorine	10.0 2.5 1.0	1, 2, 4, 8 hrs/day for 10 days 8 days 15 days	None 100% mortality 100% mortality	Turner et al. (1948)
Mussels		10.0 2.5 1.0	1, 2, 4, 8 hrs/day for 10 days 5 days 15 days	None 100% mortality 100% mortality	
Barnacles		10.0 2.5 1.0	1, 2, 4, 8 hrs/day for 10 days 4 days 7 days	95–100% mortality 100% mortality 100% mortality	
Mytilus edulis	Cl_2 injection	0.02–0.05	A few hrs	Detachment and migration	James (1967)

sea urchin to a 10 percent unchlorinated sewage-seawater mixture typically reduced fertilization success by 20 percent. A 0.5 percent dilution of moderately chlorinated sewage (11 mg/l TRC undiluted), significantly reduced fertilization. It was also determined that chlorination had more effect on sperm cells than on eggs. Eggs incubated for 5 minutes in a 0.77 mg/l hypochlorite solution and subsequently washed to remove the hypochlorite, showed no reduction in fertility. Incubation of sperm at a 0.07 mg/l hypochlorite concentration resulted in a loss of fertilization ability. This was attributed to a loss of sperm motility which was not restored after washing to remove the hypochlorite. Gametes of the echiuroid, *Urechis caupo*, and sperm of the annelid worm, *Phragmatopoma californica*, were not as sensitive to chlorine toxicity.

A number of power plant related studies have been conducted to determine the effect of chlorination of seawater on fouling organisms. Waugh (1964) observed no significant difference in the mortality of oyster larvae, *Ostrea edulis*, exposed to 5 mg/l chlorine for 3 minutes at ambient temperature, compared to control mortality. Exposure of larvae to thermal stress (10°C above ambient) and 10 mg/l chlorine for 6 to 48 minutes also had no significant effect on survival 64 hours after treatment. Barnacle nauplii, *Elminius modestus*, showed more acute sensitivity to chlorination. Residual chlorine readings in excess of 0.5 mg/l caused heavy mortality and reduced growth for survivors.

McLean (1973) simulated the conditions encountered by marine organisms passing through a power plant on the Patuxent River, Md. Intake chlorination to 2.5 mg/l residual, entrainment for approximately 3 minutes and sustained exposure to elevated temperatures for up to 3 hours were used as experimental parameters. While barnacle larvae, *Balanus sp.* and copepods, *Acartia tonsi*, were not affected by a 3 hour temperature stress of 5.5 and 11°C above ambient, exposure to 2.5 mg/l chlorination for 5 minutes at ambient temperatures caused respective mortality rates of 80 and 90 percent. The amphipod, *Melita nitida*, and the grass shrimp, *Palaemonetes pugio*, showed a delayed death response after exposure to 2.5 mg/l for 5 minutes. Nearly 100 percent mortality was observed for both species 96 hours after exposure to the chlorination. McLean (1972) showed that established colonies of the euryhaline colonial hydroid, *Bimeria franciscana*, were not greatly affected by 1 and 3 hours of exposure to 4.5 mg/l chlorination.

Turner et al. (1948) determined that continuous treatment of seawater conduits with 0.25 mg/l chlorine prevented fouling during a 90 day interval when the flow velocity was 52 cm/second or less. Intermittent treatment with 10 mg/l "residual chlorine" for 8 hours a day was ineffective in preventing fouling by anemones, mussels and barnacles.

James (1967), working in Great Britain, observed that chlorination levels of 0.02 and 0.05 mg/l caused detachment and movement of mussels in the direction of water flow through an aquarium with eventual elimination of the mussels. He concluded that the most effective way to prevent fouling by mussels was not to kill, but to discourage settling in cooling water systems by continuous low level chlorination.

Markowski (1960) compared the occurrence of marine organisms on concrete slabs placed in the intake and outfall canals of an electric generating plant. Chlorine was injected into the condensors of this plant for two hours a day at a concentration betweeen 1 and 2.5 mg/l. No vegetation was observed growing in the intake canal where dense animal populations occurred (predominantly invertebrates, Coelenterata and Polyzoa). The outfall canal contained a prolific growth of algae, *Enteromorpha sp.* but fewer invertebrates. *Balanus improvisis*, which was collected with some regularity from the intake canal was never observed in the outfall canal. The mollusk, *Eubranchus sp.* was more abundant on the intake slabs than in the outfall.

Chlorine Toxicity to Estuarine Fish

Tsai (1968, 1970, 1975) has observed decreases in the abundance and occurrence of brackish water fish species in certain areas of the Upper and Little Patuxent Rivers receiving chlorinated sewage effluent. Tsai suggests that chlorinated sewage effluent may also block the upstream migration of such semi-anadromous species as the white catfish and white perch. He attributed the blocking effect to chlorination products rather than reduced dissolved oxygen or pH resulting from organic decomposition of the effluent, Table 5.

Tsai (1973) measured the diversity index of fish upstream and downstream of 98 sewage treatment plants in Virginia, Maryland and Pennsylvania. Sewage treatment plants were categorized as Type I engineering facilities (sludge activation, aeration, sedimentation and filtration) with effluent chlorination; Type II, engineering facilities with chlorination and an effluent holding lagoon; and Type III, engineering facilities with a lagoon and effluent chlorination at the lagoon outlet. Reductions in the number of fish, number of species and the species diversity index were significant downstream of Type I and III plants. These reductions were attributed to total residual chlorine levels and turbidity. Diversity indices showed no significant changes in downstream areas associated with Type II plants.

Massive fish kills occurred on the James River, Va., during May–June 1973 (Virginia State Water Control Board, 1974). Species affected by the kill included spot, *Leiostomus xanthurus*; white perch, *Morone americana*; bluefish, *Pomatomus saltatrix*; grey seatrout, *Cynoscion regalis* and menhaden, *Brevoortia tyrannus*. A majority of the fish kill in the James River occurred adjacent to sewage treatment plants. Chlorination oxidation levels as high as 0.7 mg/l were observed in the James. Effluents from both plants showed more than 3.0 mg/l.

Distress symptoms of fish dying included spiral swimming patterns, broken vertebral columns, listless floating, inverted swimming, distension of the air bladder in some, loose body scales, mucous on the skin and hemorrhaging along the fins and body surface.

Table 5.—Summary of toxic effects of chlorinated wastes and water on marine and freshwater fishes

Species	Toxicant	Measured Residual Chlorine mg/l	Duration of Test	Effect(s)	Reference
Freshwater and brackish fishes	chlorinated sewage effluents	0.6–2.0	Long term	Decreased popn. size and diversity	Tsai (1968, 1970, 1973)
L. xanthurus Morone sp. Polatomus saltatrix C. regalis Brevoortia tyrannus	chlorinated sewage effluents	0.07–0.28	May–June, 1973	Probable kill 5–10 million fish	Virginia State Water Control Board (1974)
L. xanthurus	sodium hypochlorite	0.09 0.14 0.28	96 hrs 24 hrs 6 hrs	50% mortality 50% mortality 50% mortality	VIMS for VSWCB (1974)
O. nerka O. gorbuscha (freshwater)	chlorinated sewage effluents	0.02–0.26 0.16	24 hrs 72 hrs	100% mortality 100% mortality	Servizi and Martens (1974)
O. gorbuscha O. tshawytscha	Residual chlorine	0.5 0.5	80 min + 10 C 10 min + 10 C	50% mortality 50% mortality	Stober and Hanson (1974)
Morone americana	residual chlorine	0.08	10 min	Avoidance	Meldrim et al. (1974)
Menidia menidia		0.08	10 min	Avoidance	
F. heteroclitus		0.03	10 min	Avoidance	
Trinectes maculatus		0.03	10 min	Avoidance	
Pleuronectes platessa (eggs)	free chlorine	0.04–0.08 0.62 0.10	8 days 72 hrs 96 hrs	None 50% mortality 50% mortality	Alderson (1972)
(larvae)		0.032 0.026	48 hrs 96 hrs	50% mortality 50% mortality	
Cyprinus carpio	4-Chlororesorcinol 5-Chlorouracil (0.001 mg/l)		3–7 days	Reduced hatch	Gehrs et al. (1974)

Live box tests conducted adjacent to the James River sewage treatment plant (STP) demonstrated a correlation between rates of effluent chlorination and mortality of juvenile spot and croaker. With an average daily chlorine feed of 1,200 pounds (total flow of water was approximately 10 mgd during tests) and a measured activated oxidant level of 3.0 mg/l, caged fish suffered 100 percent mortality within 20 hours. After a cutback to a chlorine feed rate of approximately 400 pounds per day, only 20 percent mortality was observed among caged fish after 20 hours.

On-site aquaria tests confirmed the results of the cage tests. Water from an area adjacent to the outfall of the James River (STP) was pumped through aquaria containing juvenile spot. Mortalities ranged from 91 to 100 percent after 40–85 minutes of exposure prior to the cutback in chlorination. After chlorination rates were reduced, mortalities were 0–26 percent after 120 minutes of exposure.

Continuous flow laboratory bioassays were also conducted. The 96 hour LC_{50} for juvenile spot was estimated at 0.09 mg/l. The estimated 24 hour LC_{50} was 0.14 mg/l and the 6 hour LC_{50}, 0.28 mg/l.

Separate field studies on the spot, *Leiostomus xanthurus*, found up to 40 percent of juveniles from the 1973 year class exhibited deformities in the vertebral column. These abnormal forms are identifiable as a distinct year class in 1975 population samples from the James River, (Labbish Chao, personal communication).

A study of the effect of chlorinated sewage effluents on sockeye salmon, *Onchorhynchus nerka*, and pink salmon, *O. gorbuscha*, has been conducted by Servizi and Martens (1974). They used three study sites to conduct cage bioassays. The first, Site I, was adjacent to a primary treatment plant with effluents chlorinated following settling and discharged through a 600-foot pipeline directly into the receiving stream. Site II was on a stream receiving wastes from an activated sludge plant in which chlorinated effluents were discharged into a large effluent holding lagoon and retained from 30 to 60 days. Site III was located on a stream receiving effluents which were chlorinated as they left a non-aerated lagoon.

Measured chlorine residuals in the receiving stream at Site I ranged from 0.02–0.26 mg/l. These concentrations resulted in 100 percent mortality of caged sockeye fingerlings placed 30, 60 and 250 feet below the effluent discharge point. Additional tests indicated that the primary effluent without chlorination was also toxic. However, fish exposed to the unchlorinated effluent lived 10 times longer than ones exposed when effluents were being chlorinated. Toxicity of the unchlorinated effluents was attributed to MBAS and ammonia.

Tests at Site II indicated that chlorinated effluents retained for 30 to 60 days were not toxic to sockeye fingerlings and alevins and pink salmon alevins after 26 days of exposure.

In tests at Site III, with fingerling sockeye salmon, chlorinated sewage effluents (measured 0.85 mg/l) resulted in 50 percent mortality after 48 minutes. Fifty percent mortality occurred after 13 hours of exposure to the unchlorinated effluents. Sublethal exposures of fingerling sockeye salmon to the effluents from Site III (1–3 hours of exposure to 0.22 mg/l) resulted in gill damage, including hyperplasia, swollen epithelial cells, and separation of epithelium from pillar cells.

The toxicity of chlorine and heat to pink, *Oncorhynchus gorbuscha*, and chinook salmon, *O. tshawytscha*, has been determined by Stober and Hanson (1974). Juveniles of each species were tested in seawater at five chlorination concentrations, ranging from 0.05–1.0 mg/l, and four temperatures from t 0–10°C. Salmon were exposed to each matrix for 7.5–60 minutes. A decrease in the tolerance of both species to chlorination was observed with increased temperature and exposure time. The most toxic effect was observed at a t of 9.9–10°C where the LT_{50} (lethal time for 50 percent mortality) ranged from approximately 10 minutes at 0.5 mg/l for chinooks to 80 minutes for pinks.

Meldrim et al. (1974) in flowing water bioassays studied the effect of chemical pollutants on estuarine organisms. They found that white perch, *Morone americana*, consistently avoided levels as low as 0.08 mg/l at temperatures from 7–17°C. Silversides, *Menidia menidia*, also avoided 0.08 mg/l at temperatures from 8–28°C but showed a preference for 0.08 mg/l when fish acclimated to 7°C were exposed at 12°C. Mummichogs, *Fundulus heteroclitus*, and hog chokers, *Trinectes maculatus*, avoided levels as low as 0.03 mg/l.

Alderson (1972) found that the 48 and 96 hour Tl_m of free chlorine for plaice larvae, *Pleuronectes platessa*, was 0.032 and 0.026 mg/l respectively. Eggs were not affected when exposed to 0.075 and 0.04 mg/l free chlorine for 8 days, indicating that the egg membrane gives considerable protection over long periods. The 72 and 192 hour Tl_m for eggs was 0.7 and 0.12 mg/l respectively.

Gehrs et al. (1974) tested the sensitivity of carp eggs, *Cyprinus carpio*, to two of the compounds identified by Jolley, 4-Chlororesorcinol and 5-Chlorouracil. Significant reductions in the hatchability of non-water hardened carp eggs were observed in concentrations of each compound as low as 0.001 mg/l.

In California, Young (1964) observed tumor-like sores around the mouth of white croakers, *Genyonemus lineatus*, collected near the Hyperion sewage outfall in Santa Monica Bay. While there was no direct evidence to link the occurrence of lesions with chlorinated sewage effluents, a general decline in fitness of croakers and other species found in close proximity to the outfall area was observed.

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THE IMPACT OF SYNTHETIC ORGANIC COMPOUNDS ON ESTUARINE ECOSYSTEMS

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ABSTRACT

The presence and effects of synthetic organic compounds is briefly reviewed with reference to the recent literature on the estuarine ecosystem. Pesticides and industrial toxicants are discussed in general with some attention given to synergistic and modifying effects. Recommendations for future research are made which include elucidating the effects of synthetic organics at the ecosystem level.

INTRODUCTION

For the purposes considered herein, the term "synthetic organic compounds" refers to manmade compounds and includes pesticides, polychlorinated biphenyls (PCB's), hexachlorobenzene (HCB) and phthalate esters (PAE's) as well as toxic contaminants of some of these, like chlorinated dibenzodioxins and dibenzofurans.

The estuarine ecosystem has been variously defined but for the sake of simplicity it will be considered as that zone where fresh and salt water mix. This estuarine ecosystem serves a vital function in that most marine finfish and shellfish depend on a high quality estuary for some critical portion of their life history (Clark, et al., 1969; Douglas and Stroud, 1971). In addition, many salmonids and other anadromous fishes spend a variable amount of time in this habitat before ascending the rivers to spawn.

Unfortunately, the oceans are the recipients and ultimate accumulation sites for persistent pollutants like organochlorines (Dustman and Stickel, 1966; Risebrough, et al., 1972). In fact, an estimated 25 percent of all DDT applied to the land has found its way to the sea (S.C.E.P., 1970). Risebrough and his co-workers (1968a) indicate that 11 tons of DDT per year are transported down the Mississippi River to the Gulf of Mexico alone! Because of their unique physical and chemical characteristics, estuaries tend to be toxicant traps. The detritus which forms the base of the estuarine food chain may contain up to 50 ppm total DDT. Odum, et al., (1969), and Woodwell, et al., (1967), estimated that total estuarine ecosystem levels as high as 14.7 kg/hectare were possible.

DDT and other synthetic organics are termed toxic when, because of their physical or chemical properties, they interfere with normal biological functions. The interference can occur at any level, whether it be as subtle as pesticide-induced decreased growth in oysters or as gross as reproductive failure in bald eagles or mass fish mortality. Naturally-occurring toxic substances include resin from certain plants and the toxins associated with red tide organisms. By far, however, most deleterious substances find their origin with modern-day man and his efforts to promote "progress."

A logical breakdown of synthetic organic compounds which are considered in this paper along with available production and/or consumption information follows.

1. Pesticides are chemicals which kill organisms identified as "pests" and include insecticides, fungicides, piscicides, herbicides, miticides, etc. *Insecticides* are commonly broken down into: (a) chlorinated hydrocarbons (organochlorines), like DDT, aldrin, dieldrin, heptachlor, toxaphene, and chlordane; (b) organophosphates, like malathion, parathion, diazinon, and guthion; and (c) carbamates, like Sevin and zectran. *Fungicides* include dithiocarbamates (e.g., ferbam and ziram), nitrogen containing compounds (e.g., phenylmercuric acetate), triazines, quinones, heterocyclics, and inorganics like the heavy metals. Hexachlorobenzene (C_6Cl_6 or HCB) is a fungicide but is, in addition, used in organic synthesis processes. *Herbicides* are quite varied with the most common being the phenoxy acids like 2,4-D and 2,4,5-T. Frequently used aquatic herbicides include endothal and diquat which are often used in combination with a surfactant (like a detergent).

Table 1.—U.S. production of synthetic organic pesticides by class, 1967–1972*. In thousands of pounds.

	1967	1968	1969	1970	1971	1972
Fungicides	177,886	190,773	182,091	168,470	180,270	170,569
Herbicides	439,965	499,514	423,840	434,241	458,849	481,618
Insecticides, fumigants, rodenticides†	503,796	581,619	580,884	495,432	564,818	569,157
Total	1,121,647	1,271,906	1,186,815	1,098,143	1,203,937	1,221,344

* Fowler, 1974.
† Includes small quantity of synthetic soil conditioners; does not include the fumigants carbon tetrachloride, paradichlorobenzene or inorganic rodenticides.

The U.S. production of the major synthetic organic pesticides is reproduced in Table 1. In 1971, the production of synthetic organic insecticides in the United States climbed nearly 14 percent from the year before, reaching 557.7 million pounds, third highest on record (Fowler, 1973). Insecticides accounted for 49 percent of the tonnage of synthetic pesticides produced. As one can see in Table 1, the trend was reversed for 1972.

Table 2 reveals the domestic disappearance of selected pesticides for the years 1966 through 1971. Except for the aldrin-toxaphene group, there is a fairly consistent downward trend. Domestic disappearance of DDT, for instance, was 18.2 million pounds in 1971, down more than 28 percent from 1970. The consumption of the aldrin-toxaphene group continued its rise during 1972. Sales for that group (not including Strobane®) soared to 140 million pounds for 1972 (U.S. Tariff Commission, 1974).

2. "Industrial Toxicants" is a catch-all term that has been variously subdivided. *Polychlorinated biphenyls* (PCB's) are chlorinated compounds which find use in almost every sector of modern man's world and have recently come under close scrutiny (Peakall and Lincer, 1970). In the past, they have been used in such diverse products as printer's ink to swimming pool paint; however, a voluntary curtailment by Monsanto has restricted their use.

Table 2.—Domestic disappearance of selected pesticides at producers' level, United States, 1966–1971. In thousands of pounds. (Fowler, 1973).

Pesticide	1966*	1967*	1968*	1969†	1970†	1971†
Aldrin-toxaphene group**	86,646	86,289	38,710	89,721	62,282	85,005
Calcium arsenate	2,942	2,329	1,992	2,117	2,900	2,457
Copper sulfate	104,020	85,274	87,452	99,840	77,344	70,272
DDT	45,603	40,257	32,753	30,256	25,457	18,234
Lead arsenate	6,944	6,152	4,747	7,721	5,860	4,142
2,4-D	63,903	66,955	68,404	49,526	46,942	32,174
2,4,5-T	17,080	15,381	15,804	3,218	4,871	1,389

* Year ending September 30.
† Year ending December 31.
** Includes aldrin, chlordane, dieldrin, endrin, heptachlor, Strobane® and toxaphene.

Phthalate esters (PAE's) were introduced in the 1920's to overcome the problems of camphor in the plasticizer industry. Major uses of PAE's include construction products, automobile and home furnishings, clothing, food coverings and medical products. Phthalates are also found in biochemical pathways and several natural products such as poppies and tobacco leaves (Graham, 1973; Mathur, 1974). The documentation that PAE's were readily assimilated into blood from plastic storage bags and other medical devices was the original basis for the fear that the human population might be continuously exposed (Anonymous, 1973).

PCB's and PCT's (polychlorinated terphenyls) are produced under the trade name Aroclor® by Monsanto in the United States. PCB production peaked during the period 1967–1970 (Table 3). PCT production shows a similar, but later, production peak during 1970–1971. PCT's are no longer being produced and the manufacture of PCB's is directed exclusively towards the heat transfer, transformer, and capacitor sales categories. In an effort to overcome some of the potential environmental problems

Table 3.—Production of polychlorinated biphenyls (PCB's) and polychlorinated terphenyls (PCT's) by Monsanto Industrial Chemicals Company for years 1959–1973. (Pers. comm., W. B. Papageorge).

Year	U.S. Production (Thousands of Pounds)	
	PCB's	PCT's
1959	*	2,996
1960	37,919	3,850
1961	36,515	2,322
1962	38,353	4,468
1963	44,734	4,920
1964	50,833	5,288
1965	60,480	6,470
1966	65,849	8,190
1967	75,309	9,450
1968	82,854	8,870
1969	76,389	11,600
1970	85,054	17,768
1971	34,994	20,212
1972	38,600	8,134
1973	42,178	**

* Data unavailable.
** Production terminated in April, 1972.

of existing biphenyls, Aroclor 1016 was produced. Approximately 23.5 million pounds of Aroclor 1016 were sold domestically in 1973. The 1973 sales for Aroclors 1221, 1242 and 1254 were recorded at 0.04, 6.20 and 9.98 million pounds, respectively. All other PCB's showed no domestic sales (personal communication, W. B. Papageorge).

"Plasticizers" are obviously produced by a variety of manufacturers, however, phthalates (DOP, DIOP, DIDP and linear) are the major groups consumed (Table 4). During 1972, production of phthalic anhydride esters totaled 1,145,693 pounds and sales followed closely at 1,138,493 pounds (U.S. Tariff Commission, 1974).

Table 4.—Consumption of plasticizers by type (in thousand metric tons)*.

Plasticizer	1972	1973	1974
Adipates	28.0	28.4	27.3
Azelates	6.8	7.2	7.3
DOP/DIOP/DIDP	345.0	379.5	363.6
Epoxy	50.0	56.8	59.1
Linear phthalates	109.0	125.5	143.2
Polyesters	22.7	25.4	24.1
Trimellitates	8.1	8.5	10.5
Others	110.0	113.0	113.6
Total	679.6	744.3	748.7

* Source: Anonymous, initialed R. M. (1974).

PRESENCE OF SYNTHETIC ORGANICS IN ESTUARIES

Pesticides

Considering only the organochlorine pesticides, DDE (the major breakdown product of DDT) is probably the most widely distributed in fish and wildlife (see Appendix A). Being lipophilic (i.e., "fat-loving"), DDE like other organochlorines is not very soluble in water but accumulates in the fat of organisms (for overview, see Table 1 in reference entitled EPA, no date). Organochlorine pesticides are passed from prey to predator with little lost by way of excretion. This biological magnification with each transfer from one food level (i.e., trophic level) to the next results in animals at the tops of food chains acquiring inordinate amounts of these poisons (Woodwell, et al., 1967). For instance, DDE concentration reached 1,100 ppm (parts per million) in the fat of brown pelican eggs collected off the coast of California and 1,000 ppm in the eggs of the white-tailed eagle collected in the Baltic (Risebrough, et al., 1972).

Organochlorine pesticides are readily accumulated by shellfish and this characteristic has been taken advantage of to characterize the geographic distribution of pesticide contamination. As part of the National Pesticide Monitoring Program by EPA (Butler, 1973), shellfish were collected from coastal zones of the United States. Analyses of over 8,000 samples for 15 persistent organochlorines showed that DDT-type residues were ubiquitous, with the maximum DDT level at approximatlely 5 ppm. Dieldrin was the second most commonly detected compound with a maximum of 0.23 ppm. Other organochlorine pesticides found occasionally which are also extremely toxic to estuarine life, included endrin, mirex and toxaphene.

Although most organophosphate and carbamate pesticides are advertised as short-lived, there is evidence that some may not be. In an application of carbaryl (Sevin) at rates comparable to those used to control oyster pests, the chemical could still be detected in the mud 42 days post-treatment (Karinen, et al., 1967). Similarly, 14 days after a standard ground application of malathion, the organophosphate could still be found in the estuarine plant *Juncus* (Tagatz, et al., 1974).

The fungicide hexachlorobenzene (HCB), has recently been reported in several species of freshwater and some species of anadromous fish including coho salmon from Michigan and striped bass from Maryland and Florida (Johnson, et al., 1974).

Industrial Toxicants

Polychlorinated biphenyls (PCB's) are as widely distributed as DDT. Because of similar molecular shape and composition, the physical and chemical properties of PCB's also confer the same lipophilic characteristic that allows biological accumulation and food chain magnification.

Estuarine organisms like fiddler crabs and shrimp readily pick up PCB's from the sediments (Nimmo, et al., 1971a) and filter-feeding oysters accumulate these chemicals, like organochlorine pesticides, from the water (Lowe, et al., 1972).

Like the organochlorine pesticides, PCB's accumulate to high levels in organisms representing the tops of food chains. Fat from the eggs of California brown pelicans contained 200 ppm PCB's while similar samples from the Baltic white-tailed eagle contained 540 ppm (Risebrough, et al., 1972).

An ever-increasing list of industrial toxicants has been found in our waterways. Phthalate esters have been found in water collected from the Charles River in New England. Levels of 0.88–1.9 ppb were reported with higher levels associated with increasing distances upstream (Hites, 1973). Mayer, et al., (1972), reported on PAE's in selected samples from

North America. They found from 0.09 ppb DNBP (di-n-butyl phthalate) in Missouri River water to 200 ppb in Mississippi River channel catfish and 500 ppb in tadpoles. Similar values for another phthalate, DEHP (di-2-ethylhexyl phthalate), were 4.9, 400 and 300 ppb. These residue levels were roughly comparable to PCB levels in the same samples.

Although the above rivers drain directly into estuaries and one suspects that phthalates, like other adsorbed toxicants, would "salt out" upon reaching the saline environment, apparently no published research on phthalates has been directed towards that habitat.

Although the preliminary work of Bowes, et al., (1973), was directed at determining levels of chlorinated dibenzofurans and dibenzodioxins in wildlife populations exhibiting embryonic mortality, it did not reveal either of these two compounds. However, they reported hexachloronaphthalene in gull eggs but no chlorinated compounds of interest in sea lion samples.

BIOLOGICAL EFFECTS OF SYNTHETIC ORGANICS ON ESTUARINE LIFE

Pesticides

Organochlorine insecticides have been shown to interfere with almost every level of biological function tested in marine life (see Appendix B). Levels of DDT in the water as low as 0.001 ppm caused marked reduction in oyster growth (Butler, 1966a) and high levels of organochlorines have been associated with teratogenic effects in terns (Hays and Risebrough, 1972) and premature births in marine mammals (Delong, et al., 1973).

Some organochlorines, like Mirex, a chemical used to control the imported fire ant, *Solenopsis saevissima*, in the southeastern states, are particularly toxic to estuarine organisms. For example, juvenile shrimp and crabs died when exposed to one particle of mirex bait; and 1 ppb (part per billion) mirex in seawater killed 100 percent of the shrimp exposed (Lowe, et al., 1971a). Similarly, 0.1 ppm dietary dieldrin brought about maladaptive behavior in fiddler crabs (Klein and Lincer, 1973).

Some urea herbicides, like Diuron, significantly inhibit the growth of marine algae at levels as low as 1 ppb (Walsh and Grow, 1971) and a few parts per million of DDT, dieldrin or endrin is enough to reduce phytoplankton photosynthesis (Wurster, 1968; Menzel, et al., 1970).

Hexachlorobenzene has been shown to be especially toxic to birds under laboratory conditions (Vos, et al., 1968), but no tests on estuarine species have been reported to the author's knowledge.

Table 5.—Relative sensitivity of typical estuarine organisms to three major groups of pesticides. Higher numbers reflect greater sensitivity. Reworked from Butler, 1966b.

Organism	Pesticide Type		
	Herbicides	Organophosphates	Organochlorines
Plankton	1	0.5	3
Shrimp	1	1,000	300
Crab	1	800	100
Oyster	1	1	100
Fish	1	2	500

The sensitivity of a particular taxonomic group to any particular toxicant will vary appreciably. Although toxic to crustaceans, the carbamate Sevin is fairly nontoxic to fish and mammals (Lowe, 1967). In very general terms, Table 5 (reworked from Butler, 1966b) displays the relative toxicities of different pesticide groups to estuarine fauna.

In a toxicity test which included 12 insecticides and seven species of estuarine fish, the descending order of toxicity was: endrin, DDT, dieldrin, aldrin, dioxathion, heptachlor, lindane, methoxychlor, Phosdrin, malathion, DDVP, and methyl parathion (Eisler, 1970). For a more comprehensive listing of the toxic effects on estuarine life, by pesticide, the reader is encouraged to read Appendix Table 3 of EPA, no date.

California seems to have taken the lead in 1963 in describing the presence and effects of pesticides relative to water quality criteria (McKee and Wolf, 1963). This precipitated many studies and many questions. Perhaps the most important question a decision-making politician or coastal-zone administrator ought to ask with reference to toxic discharges is "How much should be allowed in our waters and what chemicals should not be applied at all near the estuaries?" Attempts have been made to answer these and similar questions. The National Technical Advisory Committee to the Secretary of the Interior (1968) zoned in on this topic and recommended that the following organochlorines not be applied near the marine habitat because of their extreme toxicity:

Aldrin	DDT
BHC	Dieldrin
Chlordane	Endosulfan
Endrin	Methoxychlor
Heptachlor	Perthane
Lindane	TDE
	Toxaphene

Mirex also has been shown to be exceptionally toxic to estuarine invertebrates like shrimp and should be considered in this category. Hexachlorobenzene is particularly toxic to birds (Vos, et al., 1968) and deserves special attention around rookeries.

A similar list for organophosphates included:

Coumophos	Fenthion	Parathion
Dursban	Naled	Ronnel

The above organochlorines and organophosphates are acutely toxic at concentrations of 5 mg/l or less and should not be permitted to exceed 50 nanograms/l. The next group they discussed is generally not quite as toxic but should not be allowed to exceed 10 mg/l in estuarine waters. This group included:

Arsenicals	2,4,5-T compounds
Botanicals	Phthalic acid compounds
Carbamates	Triazine compounds
2,4-D compounds	Substituted urea compounds

This kind of information and guidance as to allowable levels of these and most other common toxicants, including radionuclides, heavy metals, PCB's, et cetera, is presently being updated by the Environmental Protection Agency (see National Academy of Science and National Academy of Engineering, 1972).

Industrial Toxicants

A great deal of research has been carried out on the effects of PCB's on estuarine life (Appendix B). Perhaps most of it has been done at the EPA Gulf Breeze Laboratory. PCB's have been shown to significantly decrease oyster growth at levels as low as 5 ppb (Lowe, et al., 1972) and be lethal to shrimp at 1 ppb (Nimmo, et al., 1971b). Duke, et al. (1970) showed that crabs concentrated the PCB Aroclor 1254 and 72 percent of the shrimp exposed to 5 ppb died after day 10. Hansen, et al. (1974a) demonstrated that estuarine fishes and shrimp displayed varying degrees of avoidance to the same PCB at levels 0.001 to 10 ppm. Bioassays with Aroclor 1254 indicated that 5 ppb caused mortality to estuarine fish and the effect was delayed (Hansen, et al., 1971). In response to the change in emphasis of PCB production and subsequent increase in Aroclor 1016 manufacture, Hansen and co-workers (1974b) established the acute 96-hour LC_{50}'s for estuarine shrimp, fish, and oyster.

The biochemical effects of PCB's have also come under scrutiny. Keil, et al. (1971) tested the effects of Aroclor 1242 (0.01–0.1 ppm) on marine diatoms and found that it inhibited growth, RNA synthesis and chlorophyll production. Aroclor 1221 has been shown capable of impairing osmoregulation in the killifish at relatively high levels (7.5–75 ppm) by Kinter, et al., (1972).

Although no work has apparently been done on the effects of PCB's on estuarine fish-eating birds, some data are available on ducks. Friend and Trainer (1970) showed a marked influence of Aroclor 1254 on the duck's susceptibility to viral infection. Heath, et al. (1972), testing a series of PCB's, revealed that toxicity was positively correlated with degree of chlorination and Haegele and Tucker (1974) established the effect of 1254 on eggshell thinning.

Very little toxicological work has been done with dioxins, dibenzofurans, and phthalates and nothing has been directed at the estuarine habitat, to the author's knowledge. Miller, et al. (1973) reported on the effects of tetrachloro-dibenzo-dioxin (TCDD) on various aquatic organisms. Approximately 50 percent of the young coho salmon exposed to 131 mg/l died by day 20. They also showed a marked growth inhibition by TCDD on both salmon and rainbow trout.

Zitko and his colleagues (1973) reported on the acute and chronic oral toxicity of chlorinated dibenzofurans to immature brook trout. They concluded that 2,8-dichlorodibenzofuran has a low acute toxicity to that species since even a high level of 122 mg/kg produced no mortality.

Work on phthalate esters has been limited to freshwater or anadromous organisms. In an effort to establish LC_{50} values for freshwater organisms, Mayer and Sanders (1973) reported DNBP to be less toxic to rainbow trout (96-hour $LC_{50} = 6.5$ mg/l) than to the other fish tested. Phthalate esters are metabolized by freshwater fishes (Stalling, et al., 1973) and both DEHP and DNBP are apparently not acutely toxic to freshwater invertebrates. Sanders, et al. (1973) reported that although invertebrates rapidly accumulate these compounds, their 96-hour TL_{50} ($2.1 - > 32$ mg/l) is appreciably greater than DDT, by comparison. However, the TL_{50} values for aquatic organisms are 700 to 11,000 times that which inhibited reproduction in one of the invertebrates tested (water fleas).

Synergism and Modifying Effects

No report, however brief, on the effects of synthetic organics on estuarine life would be complete without including the area of synergistic effects and modifying factors. The term "synergism", unfortunately, has many definitions. For our present needs, we will consider it to mean more than the anticipated additive effects.

This subject has been addressed in depth elsewhere (Livingston, et al., in press) however, a few examples particularly germane to the estuary will follow. Once again, most work in this area has been done in freshwater, however, Lowe, et al. (1971b) reported that oysters exposed to a mixture of 1 mg/l each of DDT, toxaphene and parathion showed reduced growth and histopathological effects. When these mollusks were exposed to the individual pesticides, similar results were not observed.

Eisler (1970) reported on the modifying factors affecting the toxicity of organochlorines and organophosphates to the mummichog, an estuarine fish. The toxicity of organophosphates increased with increasing temperature and salinity and decreasing pH. The toxicity of organochlorines was greatest at intermediate temperatures (20–25°C) and least at an intermediate pH (7–8). Salinity had little effect on organochlorine toxicity.

Nimmo (1973) reported that sublethal levels of the PCB, Aroclor 1254, became lethal to estuarine penaeid shrimp when the test organisms were stressed by reduced salinity. Since this species is migratory and experiences a wide variation in salinity, this finding is particularly significant.

The effect of temperature may be of paramount importance in modifying the toxicity of pesticides to estuarine invertebrates. For example, Koenig, et al. (in preparation) found that blue crabs contaminated with DDT did not die in a field experiment until a cold front caused significant reductions in water temperature.

Effects of Synthetic Organics at the Estuarine Ecosystem Level

With all due deference to the title of this report, pitifully little research has been addressed to the ecosystem level. Although a variable amount of effort has gone into testing the effects of particular toxicants under field conditions (see Appendix C), this is still not approaching the problem on the ecosystem level.

Odum and others have developed methods for simulating ecosystem energy and material flow on analog computers, but this approach is still twice-removed from reality. On the other hand, such models often indicate what types of information are lacking and also have the advantage that the effects of even extreme manipulations can be tested through many generations or seasonal cycles without any damage to the real world.

Even at the community level, little has been done with respect to the effects of synthetic organics. A variety of community parameters have been suggested as reflectors of a community's health. Margalef's "species richness" and Peilou's "species diversity and evenness" are but a few. Researchers are only now finding out that many of these parameters are not the panaceas they thought they were. The main problem lies with trying to use these techniques out of the context for which they were originally intended.

If it is possible to consistently and accurately describe some ecosystem parameter, then it ought to be theoretically possible to quantitate a change in that parameter. The absence of this kind of effort in the estuarine and other habitats is merely a reflection of our current inability to describe such changes, not evidence of its non-existence.

RECOMMENDED RESEARCH

It goes without saying that there are existing programs that have to continue. One such program is the National Pesticide Monitoring Program. It is also imperative that we have an established framework, like the one at the Gulf Breeze Laboratory, whereby chemicals which come under public scrutiny, can be quickly tested.

As an overview, emphasis in future research should be given to determining the significance of the residues being reported in the literature. This can be accomplished by stressing the diagnostic aspects of experimentation during the planning stage and encouraging toxicological studies that have direct relevance to the real world.

In this light, the area of field-testing toxicants has progressed in a manner that reflects individual idiosyncrasies and the idiomatic characteristics of the funding and/or research organization (Appendix C). Efforts should be made to, at least, roughly standardize field-testing techniques with a keen awareness of the possible modifying and synergistic effects that one will encounter in the estuary. Interpretation of field exposures will require coordinated efforts in the laboratory under less real, but more controlled, conditions. It is only there that statistically and logistically complicated designs can reach fruition and elucidate specific modes of action, synergy, latent effects, food-chain magnification, and so forth.

On the gobal scene, interdisciplinary efforts should be made to more thoroughly characterize the kinetics, marketing patterns, and use of widespread synthetic organic compounds, like phthalate esters, other plasticizers, chlorinated dibenzofurans, and dioxins and HCB. We need to know more about their environmental kinetics, especially their metabolism in soil and water.

As to specific chemicals that need experimental attention, PAE's, HCB, dioxins and dibenzofurans are high on the list.

PAE's are widespread in freshwater fish with higher residues appearing to be associated with industrial areas (Stalling, et al., 1973). They have been shown to be more toxic to aquatic organisms than warm-blooded animals. These esters disturb reproduction and growth in aquatic invertebrates and fish yet nothing is known about their effects on estuarine species.

Although not widely reported in the literature, HCB has been found in environmental samples (Holden, 1970). In view of the possible analytical confusion with benzene hexachloride (BHC), HCB may be even more widespread. With this potential and the documented toxicity of this compound to birds in mind (Vos, et al., 1968), the effects of HCB on fish-eating birds is of concern.

Initial work with the dioxin TCDD indicates important effects on the growth and reproduction of anadromous and freshwater species (Miller, et al., 1973). Again, nothing is known about the effects on estuarine species.

Dibenzofurans were not particularly lethal to the trout they were tested on (Zitko, et al., 1973), however, nothing is known about their sublethal effects. In addition, because of different osmoregulatory mechanisms, the effects on euryhaline species may be considerably different.

As to the level of emphasis and the parameters that need attention, efforts should be made to characterize effects at the ecosystem and/or community level. This is the final biological-physical-chemical integration that will reflect individual perturbations at any sublevel if, in fact, they are significant. As a prelude to this, more intensive research is necessary on the sublethal effects, with special emphasis on behavior and biochemistry. In terms of the experimental design of laboratory studies, more attention should be given to synergistic effects and latent responses. With reference to the former, research aimed to elucidating the modifying effects of sewage and storm runoff is long overdue.

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APPENDIX A

Synthetic Organic Residues Found in Estuarine Organisms

Taxa	Pesticides	Industrial Toxicants	Comments	Reference
PISCES				
Fish	DDT, DDE, DDD		Shows "biological magnification"	Woodwell, et al., 1967
Fish Britain	DDT, DDE, DDD, BHC, heptachlor		Residues vary with species	Moore & Tatton, 1965
Seatrout eggs	DDT		Causes spawning failure	Butler, 1969
Fish and fish oil	DDE, DDD	PCB's	Residue greater in industrialized coastal area	Jensen, et al., 1969
Fish in estuary		Aroclor 1254	Appears to have no effect on juvenile stage—(pinfish)	Duke, et al., 1970
Fish	DDT		Residues up to 16 ug/g	Butler, 1968
Pacific fish	DDT		Highest concentration in coastal fish	Risebrough, et al., 1967
Fish	DDT		Mortality following tidal ditch spray	Croker & Wilson, 1965
Pacific fish-livers	BHC, heptachlor, aldrin, toxaphene, chlordane, methoxychlor, dieldrin, endrin, DDE, DDD, DDT		Bottom dwellers contain higher concentration than pelagic	Duke & Wilson, 1971
Atlantic fish	DDE, DDT, DDD, hexachlorobenzene	Aroclor 1242, 1254, 1260	Higher concentration in surface swimmers	Zitko, 1971
Fish estuarine	DDT		Fatal to predators at different trophic levels	Butler, 1966c
Atlantic fish		Phenoclor DP6	Lower chlorinated PCB's more frequent in fish than birds	Koeman, et al., 1969
Processed and unprocessed Canadian fish		Phthalates	Low levels were found in 21 samples of fish available to the Canadian consumer	Williams, 1973
Many species	DDE	PCB's	Compilation of residue data	Zitko & Choi, 1971
Many species		Aroclor 1254	Geographic comparisons	Risebrough & de Lappe, 1972
Groupers; Gulf of Mexico and Bahamas	DDE, DDT	Aroclor 1260	Geographic comparisons	Giam, et al., 1974
Fish		HCB	Reported 0.002 ppm (salmon eggs)—0.11 ppm (menhaden oil)	Johnson, et al., 1974
MAMMALIA				
Dolphin	DDT		Concentrated in blubber	Butler, 1966c
Dolphin and seal	dieldrin, DDT, DDE, TDE		Largest amounts in blubber	Holden & Marsden, 1967
Seals	DDE, DDD	PCB	Level consistent throughout all parts of body	Jensen, et al., 1969
AVES				
Bald eagle	DDT, DDD		Caused death?	Reichel, et al., 1969a
Seabirds; North Atlantic	DDT	Aroclor 1254	Present in nonmigrating Arctic birds	Bourne & Bogan, 1972
Seabirds and their predators	DDT	PCB	Data on DDT/PCB ratios	Risebrough, et al., 1968b
Bald eagle and eggs	DDE, dieldrin	PCB	From many areas around North America	Wiemeyer, et al., 1972
Bald eagle and golden eagle	DDE, DDD, dieldrin, DCBP, endrin, heptachlor		Higher levels in bald eagles	Reichel, et al., 1969b
Terns	DDT, DDE	Aroclor 1254	Deformities in young	Hays and Risebrough, 1972
Sea birds (Britain)	DDT, HEOD		Seasonal variation	Robinson, et al., 1967
Sea birds and eggs	DDE, dieldrin	Aroclor 1254	Highest residues in freshwater fish-feeding birds	Prestt, et al., 1970

Taxa	Pesticides	Industrial Toxicants	Comments	Reference
Brown pelican eggs	DDT	PCB	Eggshells thin	Schreiber & Risebrough, 1972
British sea birds	DDE	PCB	More PCB's than organochlorines	Holmes, et al., 1967
Sandwich tern	telodrin, dieldrin, endrin, DDE	Phenoclor DP6	Population decline due to pesticides	Koeman, et al., 1967
Birds and eggs		Phenoclor DP6	Some parts of mixture metabolized	Koeman, et al., 1969
Brown pelicans, petrels and shearwaters		Aroclor 1254	Geographic comparisons	Risebrough & de Lappe, 1972
Cormorant and gull	DDE, DDT	Aroclor 1254	No dioxins nor benzofurans found in eggs and tissue	Zitko, et al., 1972
Gull eggs	DDE	PCB's	Hexachloronaphthalene present but no dioxins nor benzofurans found	Bowes, et al., 1973
Eggs of Florida fish-eating birds	DDE, dieldrin	Aroclor 1254	2–20 ppm (OD) DDE; 1–161 ppm PCB	Lincer & Salkind (sic), 1973
Brain and eggs of endangered petrel	DDE		0.23–0.38 ppm (OD) in eggs	King & Lincer, 1973
Bald eagles		Aroclor 1254	Confirmation by mass spectrometry	Bagley, et al., 1970
Many species of fish-eating birds	DDE	PCB's	Compilation of residue data	Zitko & Choi, 1971
Shorebirds and fish-eating birds	DDE	PCB's	Compilation of residue data and comparison of DDE residues to eggshell thickness	Keith & Gruchy, 1972
Heron egg, Britain		PCB	Application of mass spectrometry	Richardson, et al., 1971
British seabird eggs	dieldrin, DDE, DDT, BHC, heptachlor		Higher levels in eggs of larger birds	Moore & Tatton, 1965
Sea birds	DDT, DDE, DDD		"Biological magnification"	Woodwell, et al., 1967
Pacific sea birds	DDT, DDE, DDD		Residue levels higher in California birds than northern migrants	Risebrough, et al., 1967
Swedish sea birds	DDE, DDD	PCB	"Biological magnification"	Jensen, et al., 1969
Birds and eggs, Long Island, N.Y.	DDT and its metabolites, dieldrin		Residues in eggs of fish-eating birds	Foehrenbach, 1972
MOLLUSCA				
Mollusks, Britain	dieldrin, DDT, DDE, DDD, heptachlor, BHC		Traces present in all mollusks tested	Moore & Tatton, 1965
Oysters	DDT		Rate of shell growth indicator of pollution level	Butler, 1969
Mussels	DDE, DDD	PCB's	Lower average concentration in less industrialized area	Jensen, et al., 1969
Oysters		Aroclor 1254	Shell growth of juvenile completely inhibited upon exposure	Duke, et al., 1970
Oysters	DDT		A good monitoring organism	Butler, 1968
Mussels	DDT	PCB		Koeman, et al., 1969
Oysters, clams, mussels, snails	DDT, DDE, DDD, dieldrin		Amounts varied with proximal land use	Foehrenbach, 1972
PLANKTON				
Phytoplankton	DDT, DDD, DDE		Concentrations tripled 1955–1969	Cox, 1970
Zooplankton	DDT, DDE, DDD		Low residues shown for low trophic level	Woodwell, et al., 1967
CRUSTACEA				
Sandcrab	DDT, DDE, DDD		Concentrations due not only to agriculture usage but industrial waste discharge (DDT plant)	Burnett, 1971
Crayfish and shrimp		Aroclor 1254	Concentrate rapidly to equilibrium	Sanders & Chandler, 1972

Taxa	Pesticides	Industrial Toxicants	Comments	Reference
Shrimp	DDT, DDE, DDD		Sensitivity correlated to substantial reduction in population	Woodwell, et al., 1967
Shrimp, crabs		Aroclor 1254	Higher concentration than oysters	Duke, et al., 1970
Fiddler crabs	DDT, DDE, DDD, dieldrin		Residue levels in Uca	Foehrenbach, 1972
MISCELLANEOUS				
Aquatic insect larvae		Aroclor 1254	Failed to metamorphose to adult stage	Sanders & Chandler, 1972
Sea urchin, snail	DDT compounds		All insecticide in gonads of sea urchin	Risebrough, et al., 1967
Water & sediment		Aroclor 1254	A gradient with distance from pollution source	Duke, et al., 1970
Suspended organic matter; San Francisco Bay		Phthalate esters	Utilization of mass spectrometry methods	Simoneit, et al., 1973
Crown of thorns; Pacific		PCB (similar to 1254)	Estimated levels of 0.01–0.05 ppm	McCloskey & Deubert, 1973
Green sea turtle eggs; South Atlantic	DDE	1242, 1248, 1254	0.24–1.81 ppm PCB (lipid basis); ND-0.08 ppm DDE	Thompson, et al., 1974
River water; New England		Phthalate	Reported 0.9–1.9 ppb	Hites, 1973

APPENDIX B

Effects of Synthetic Organic Compounds on Estuarine Organisms

Treatment	Taxa	Organochlorine Insecticides	
		Observed Effects	Reference
Seven pesticides; .1 to 5 ppb; 5 year monitoring	clams oysters	Different species take up pesticides at specific rates. Sublethal long range effects more significant than acute toxicity.	Butler, 1971
Endrin, aldrin, heptachlor	oysters	Linear relation between concentration and shell growth.	Butler, 1965
Dieldrin, kepone	oysters	Sharp threshold of toxicity relative to shell growth.	
DDT, 1 ppb	clam	No effects for 3 months. 30% mortality 4th month.	
DDT-toxaphene, parathion—together and separately, <3.0 ppb	oysters	10% less body weight. Tissue changes, loss of resistance to parasite.	Lowe, et al., 1971b
12 pesticides ranging from lindane, 9.10 ppm to CoRal 0.11 ppm	oyster eggs & larvae	50% of eggs develop normally at given concentrations.	Davis & Hidu, 1969
12 pesticides ranging from lindane & aldrin <10 ppm, to N3514, <1.0 ppm	clam eggs	Same as above.	
DDT >1 ppm <1 ppm	oyster	Remain closed or show spasmodic shell movements at higher levels; decrease in shell deposition at lower levels.	Butler, 1966a
DDT in oil spray, .2–1.6 lb/A	isopods amphipods prawns	High mortality. High mortality. High mortality.	Springer, 1961
0.3 to 0.8 lb/A	blue crab	10–100% mortality.	
Repeated applications	spiders crabs insects marsh crabs red mites fish molluscs snails turtles frogs mammals	High mortality. High mortality. High mortality. Resistant. Not affected. Some deaths. Not affected. Not affected. Not affected. Not affected. Not affected.	
Aldrin 0.2 lb/A	insects prawns crabs fish	More affected than by DDT. Less affected than by DDT. Less affected than by DDT. Less affected than by DDT.	Springer, 1951
Gamma BHC 0.2 lb/A	crabs	Most toxic insecticide tested.	
DDT—2 ppm fed	fish shrimp	50% mortality. DDT in dead laboratory animals less than in seemingly healthy ones in field.	Butler, 1966c
DDT 1–500 ppb	phytoplankton	Photosynthesis reduced.	Wurster, 1968
DDT 0.2 lb/A	fish crabs	Some mortality among animals that could not avoid pesticides.	
Strobane 0.3 lb/A	3 species crabs	Same as DDT.	
BHC 0.1 lb/A	fiddler crabs	Fiddler crabs lost ability to escape predators.	George, et al., 1957
DDT in oil spray, .3 to 16 lb/A	snakes amphibians lizards turtles	High mortality following symptoms of poisoning.	Herald, 1949
Dieldrin, .0006 to .012 ppm	sailfin molly	Killed by 72 hours. Raised serum glutamic oxaloacetic transaminase to 1500 to 1700 units.	Lane & Scura, 1970

Treatment	Taxa	Organochlorine Insecticides — Observed Effects	Reference
.003 ppm		Survived to 120 hours. Raised SGOT to 6006-11,954 units.	
Dieldrin .012 to .003 ppm .0015 and .0075 ppm	sailfin molly	100% mortality 1st to 31st week. More than half survived to week 34; growth and reproduction adversely affected.	Lane & Livingston, 1970
Aldrin & dieldrin	fiddler crab trout crayfish tissues	Selectively inhibited cholinesterase activity in homogenized tissues. Cholinesterase very sensitive to small amounts of pesticide.	Guilbault, et al., 1972
DDT 1.0 ppb/2 wks 0.1 ppb/5 wks	fish	Maximum concentration reached at 2 weeks. 38,000 x test water conc. Loss of 78–87% in 8 weeks.	Hansen & Wilson, 1970
DDT, endrin 0.1 to .00001 ppm	minnows	Avoided water containing pesticides. Did not distinguish concentration differences.	Hansen, 1969
DDT 50 ppm	eel intestine	Inhibition of water absorption. Inhibition of (Na^+ and K^+) activated Mg^{2+}-dependent adenosine triphosphatase.	Janicki & Kinter, 1971
Mirex, 1–5 particles of bait in standing sea water or Mirex in flowing sea water 1.0 to 0.1 ppb	juvenile shrimp juvenile shrimp juvenile blue crab fiddler crabs fish	40 to 100% mortality Up to 100% mortality delayed until shrimp in Mirex free water. Up to 96% mortality, delayed. Accumulated Mirex in bodies. Accumulated Mirex in bodies. Gill parasites reduced.	Lowe, et al., 1971a
DDT 2–5 μg/g	shrimp crab fish pinfish	35–100% mortality. Accumulated DDT in bodies.	Butler, 1968
DDT <1 ppm	oyster	Feeding & shell growth stopped. Erratic shell movements.	Butler, 1967
DDT 2–4 ppm on food	fish shrimp	50% mortality in 2–4 weeks.	
DDT in flowing sea water 0.1 ppm 0.05 ppm	shrimp shrimp	Lowered Na^+ and K^+ in hepatopancreas, change in Na^+ and K^+ only after day 20.	Nimmo & Blackman, 1972
DDT in flowing sea water 10 ppb	juvenile shrimp	100% mortality.	Nimmo, et al., 1971b
DDT 0.05 to 0.17 ppb 0.12 to 0.20 ppb	shrimp	DDT concentrates in hepatopancreas. Flushed from hepatopancreas within 6 weeks. 100% mortality 18 to 28 days.	Nimmo, et al., 1970
Mirex .001, .1, 1.0 & 10 ppb	crab larvae	Larval stages prolonged. Increased mortality.	Bookhout, et al., 1971
DDT 10 ppm on detritus	fiddler crabs	100% lost coordination by day 5. Three-fold accumulation in claw muscles.	Odum, et al., 1969
Toxaphene	fish shrimp, crabs	Established 96 hour TL_{50} values; includes data on synergy and histopathology.	Courtenay & Roberts, 1973
DDE	duck	Eggshell thinning complete after 4 days on 40 ppm diet; electron microscopy.	Peakall, et al., 1973
DDE, dieldrin	duck	20 ppm DDT or 10 ppm dietary doses resulted in eggshell thinning.	Davison & Sell, 1974
DDT group, dieldrin, heptachlor, toxaphene	duck	Established effects on eggshell thinning.	Haegele & Tucker, 1974
DDE	duck	LC_{50} values varied with age of ducks (1200–1600 ppm).	Friend & Trainer, 1974
Dieldrin; .1–50 ppm	fiddler crabs	Levels correlated with maladaptive behavior and mortality. Latent effects.	Klein & Lincer, 1973

Treatment	Taxa	Organophosphate Insecticides — Observed Effects	Reference
Parathion	oysters	Sharp threshold of toxicity relative to shell growth.	Butler, 1965
4 pesticides ranging from guthion .62 ppm, to TEPP 10.	oyster eggs clam eggs	50% of eggs develop normally.	Davis & Hidu 1969
Malathion, dursban; 10–.01 ppm	minnows	Did not avoid Malathion. Did avoid Dursban.	Hansen, 1969

Treatment	Taxa	Organophosphate Insecticides — Observed Effects	Reference
Paraoxon, DDVP parathion, methyl parathion	fiddler crabs trout crayfish tissues	Selectively inhibited cholinesterase activity in homogenized tissues. Cholinesterase sensitive to small amounts of pesticide.	Guilbault, et al., 1972
Malathion, naled, guthion and parathion	fishes and pink shrimp	Revealed comparative AChE inhibition.	Coppage & Matthews, 1974
Parathion	duck	Established effect on eggshell thinning.	Haegele & Tucker, 1974

Treatment	Taxa	Carbamate Insecticides — Observed Effects	Reference
Sevin 0.1 ppm	juvenile fish	Survived normally, neural parasite may not be related to toxicant.	Lowe, 1967
Sevin 0.01–10 ppm	minnows	Did not avoid Sevin.	Hansen, 1969
Sevin	gastropod (oyster drill)	Swelling at 6–7 hours exposure.	Wood & Roberts, 1963
Matacil, mesurol, zectran, baygon, sevin	fiddler crabs crayfish trout	Selectively inhibited cholinesterase activity in homogenized tissues. Cholinesterase very sensitive to small amounts of pesticides.	Guilbault, et al., 1972

Treatment	Taxa	Herbicides, Bacteriocides, etc. — Observed Effects	Reference
12 herbicides ranging from amitrol 733.70 ppm to silvex 2.4 ppm nemagon, sevin	oyster eggs clam eggs	50% developed normally.	Davis & Hidu, 1969
19 bacteriocides, algicides, fungicides from untinted sulmet 1000 ppm to phygon .014 ppm	oyster eggs clam eggs	50% developed normally.	
2,4-D acid	duck	Established effect on eggshell thinning.	Haegele & Tucker, 1974
4 herbicides in sea water	6 genera algae	Carbohydrate concentration depressed. Varies with salinity.	Walsh & Grow, 1971
Nitrilotriacetic acid	phytoplankton	Low toxicity as long as chelate:metal ratio favorable; NTA alone, trace metal deficiency.	Erikson, et al., 1970
2,4-D, 0.01–10 ppm	minnows	Avoidance of herbicide.	Hansen, 1969
Antimycin A 7 ppb	38 species fish other fish oysters plankton crabs	Killed in three days. No effect.	Finucane, 1969
Polystream (chlorinated benzenes)	oyster drill	Under recommended dosage, 50% of animals killed by day 7.	Wood & Roberts, 1963

Treatment	Taxa	Industrial Toxicants — Observed Effects	Reference
Aroclor 1254 .94–100 ppb	juvenile shrimp	51 to 100% mortality.	Nimmo, et al., 1971b
Aroclor 1254 2.5–3.5 ppb	adult shrimp	50% mortality, accumulated in hepatopancreas. 23% died after return to sea water.	
Aroclor 1254 in Corexit 7664 colloidal solution emulsions	Gammarus Gammarus	Lethal threshold 0.001 to 0.01 ppm. Lethal threshold .01 to .1 ppm.	Wildish, 1970
Aroclor 1254 1 ppb to 56 days 5 ppb 14–45 days	fish	No apparent effect at 1 ppb; Mortality occurred, though delayed at 5 ppb.	Hansen, et al., 1971
Aroclor 1254 100 ppb 48 hours	shrimp oysters pinfish	100% mortality. Shell growth inhibited. Concentrated PCB.	Duke, et al., 1970
5 ppb 20 days	shrimp crabs	72% mortality after day 10. Concentrated PCB.	

Treatment	Taxa	Industrial Toxicants	
		Observed Effects	Reference
Aroclor 1242 and Aroclor 1254 + radiocarbon	phytoplankton	Radiocarbon uptake reduced at as low as 1–2 ppb.	Moore Harriss, 1972
Aroclor 1242 in water .01 to .1 ppm	marine diatom	Inhibited growth, RNA synthesis and chlorophyl index.	Kiel, et al., 1971
Aroclor 1254 in sediment 61.0 ppm (dry wt.) to 1.4 ppm for 30 days	shrimp crabs	Amount of PCB residue in animal varies with amount in substrate.	Nimmo, et al., 1971a
Aroclor 1221; 7.5–75 ppm	killifish	Decreased ability to osmoregulate.	Kinter, et al., 1972
Aroclor 1254	shrimp	60% died at 9.1 ppb (7 day exposure); no significant mortality at 0.62 ppb.	Nimmo, et al., 1974
Aroclor 1254; 0.001–10 ppm	shrimp fishes	Demonstrated that some animals could avoid Aroclor 1254 under laboratory conditions.	Hansen, et al., 1974a
Aroclor 1016	oyster shrimp fish	Established acute 96 hour LC_{50}'s.	Hansen, et al., 1974b
Aroclor 1254	oyster	5 ppb for 24 weeks reduced growth and produced tissue atrophy and degeneration.	Lowe, et al., 1972
Aroclor 1254	duck	Showed PCB influence on susceptibility of birds to virus.	Friend Trainer, 1970
Aroclor 1232, 1242, 1248, 1254, 1260, 1262	duck	Toxicity positively correlated with percent chlorine.	Heath, et al., 1972
Aroclor 1254	duck	Established effect on eggshell thinning.	Haegele & Tucker, 1974
Dioxin (TCDD) in water and food	salmonids	Marked decrease in growth; latent effect.	Miller, et al., 1973
Dibenzofurans	salmonids	Dietary doses up to 122 mg/kg resulted in no mortality.	Zitko, et al., 1973
Phthalate ester	rainbow trout	LC_{50} (96 hour) = 6.47 ppm.	Mayer & Sanders, 1973

APPENDIX C

An Overview of the Field-Testing of Pesticides

Ecosystem	Pesticide	Observed Parameters	Taxa	Reference
F/W Pond	DDT	Mortality	Fish Plankton Benthic Inverts. Reptiles Birds Mammals Terr. Insects	Tarzwell, 1948
Enclosed area of F/W Pond	DDT	Population	Fish	Tarzwell, 1948
Tidal Marsh	DDT	Mortality Gross behavior Growth (snails)	Fish Crabs Shrimp Insects Mollusks Amphipods Worms Mites Birds	Springer and Webster, 1951
Tidal Marsh	Strobane, DDT & HCB	Mortality Gross behavior on fiddlers	Fish Crabs Birds Mammals	George et al., 1957
Tidal Marsh Ditch	Dieldrin	Mortality	Fish Crabs	Harrington & Bidlingmayer, 1958
Tidal Marsh	DDT, aldrin, dieldrin & BHC	Mortality	Fish Prawns Anthropods Iso- and Amphipods Crabs Worms Mollusks Birds	Springer, 1961
Tidal Marsh Ditch	DDT	Mortality & population; Residue monitoring	Fish Crabs	Croker & Wilson, 1965
Estuaries	2,4-D	Mortality	Fish Crab Oysters Clam	Rawls, 1965
Salt Marsh F/W Pond	Dursban	Mortality	Fish Shrimp Crabs Oyster Insects Terr. Verts.	U.S.D.I., 1967a
Mangrove Swamp	Dibrom	Mortality Cholinesterase Population	Fish Crab Mammals Birds Insects	U.S.D.I., 1967b
Salt Marsh	Dursban	Mortality Monitoring	Fish Crab Shrimp Birds	Ludwig, et al., 1968
Tidal Marsh	Dursban	Mortality Cholinesterase inhibition	Fish Crabs Shrimp Mammal Bird	U.S.D.I., 1968
Salt Marsh	Malathion	Mortality Cholinesterase	Fish Crab Shrimp Mollusks	Tagatz, et al., 1974

TRACE METALS IN THE OCEANS: PROBLEM OR NO?

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ABSTRACT

Increased input of mercury to the estuarine environment resulted in bioaccumulation in marine food chains that affected man (Irukayama, 1966). Toxic effects of other metals on marine animals has been demonstrated under laboratory conditions. However, cause and effect between elevated environmental metals levels and toxicity to marine animals has yet to be conclusively demonstrated under field conditions. Municipal waste water treatment plants, dredging and spoiling activities, and the dumping of sewage sludge and industrial wastes are the major sources of metals to the marine environment. These sources are likely to increase in the future unless the Federal Water Pollution Control Act Amendments of 1972 (PL-92-500) are carefully enforced.

INTRODUCTION

Estuaries, because they are landward extensions of the sea, have become centers of industrial, commercial, and related activities. As a consequence, estuaries have received an increasing input of metals, the byproducts of modern industry and technological advancement. Metals can be introduced indirectly from contaminated rivers and land runoff or directly by pumping from land based industries and municipalities, ship and barge discharges, and aerial fallout (Merlini, 1971). When viewed as a whole, ocean systems appear to be beyond compromise in their ability to dilute introductions from man's activities—after all, the continental masses are continually bathed in their oceans and seas. Where then do problems occur?

Ocean waters, especially estuaries, are not uniformly mixed and non-uniform dilution can cause local concentrations of metals. Metals tend to be concentrated at air-sea, sediment-water, or freshwater-saltwater interfaces and boundaries between water and living or dead particles (Fig. 1). Some metals discharged even in small quantities can be accumulated to alarming and lethal levels by certain marine biota. Seafoods harvested by man can become extensively impacted when excessive metals are added to the sea. A classic example of the human aspect of this problem first received widespread attention when mercury poisoning occurred in Japan in 1953 through consumption of contaminated fish and shellfish (Irukayama, 1966).

Sediments in estuaries naturally tend to have relatively high levels of metals. As long as the biological component of estuarine benthic systems (bottom related systems, including sediments, plants, and animals living on or in them) is alive and well, the naturally enriched sediments appear to be processed and metals are biologically recycled into the system. However, frequently these benthic systems are stressed beyond the biological breaking point, and the biota is eliminated or drastically reduced. If the biological recycling system is destroyed, an anaerobic sedimentary system develops, and among other things, becomes a metals sink. The elements that were formerly recycled accumulate to orders of magnitude above those observed in biologically active systems. There is a "leaching out" of these metals, but the rates now controlled primarily by physical-chemical processes go on at a very slow pace.

Two problems emerge when sediments become sinks rather than recyclers for metals.

1) Due to relatively rapid sedimentation that occurs in upper estuarine areas, channels must be dredged. Very frequently, dredged materials are anaerobic and rich in elemental composition. Where can they be dumped with assurance that those materials which enrich the sediment may not prove noxious to man directly or indirectly through reduction in marine resources?

2) If an estuary which receives feedback from its sediments in the form of nutrients—both organic and inorganic—loses a part of this benthic recycling activity, what are the long-term and short-term effects? For example, does the creation of a metal sink in estuarine sediments affect plankton productivity and species composition?

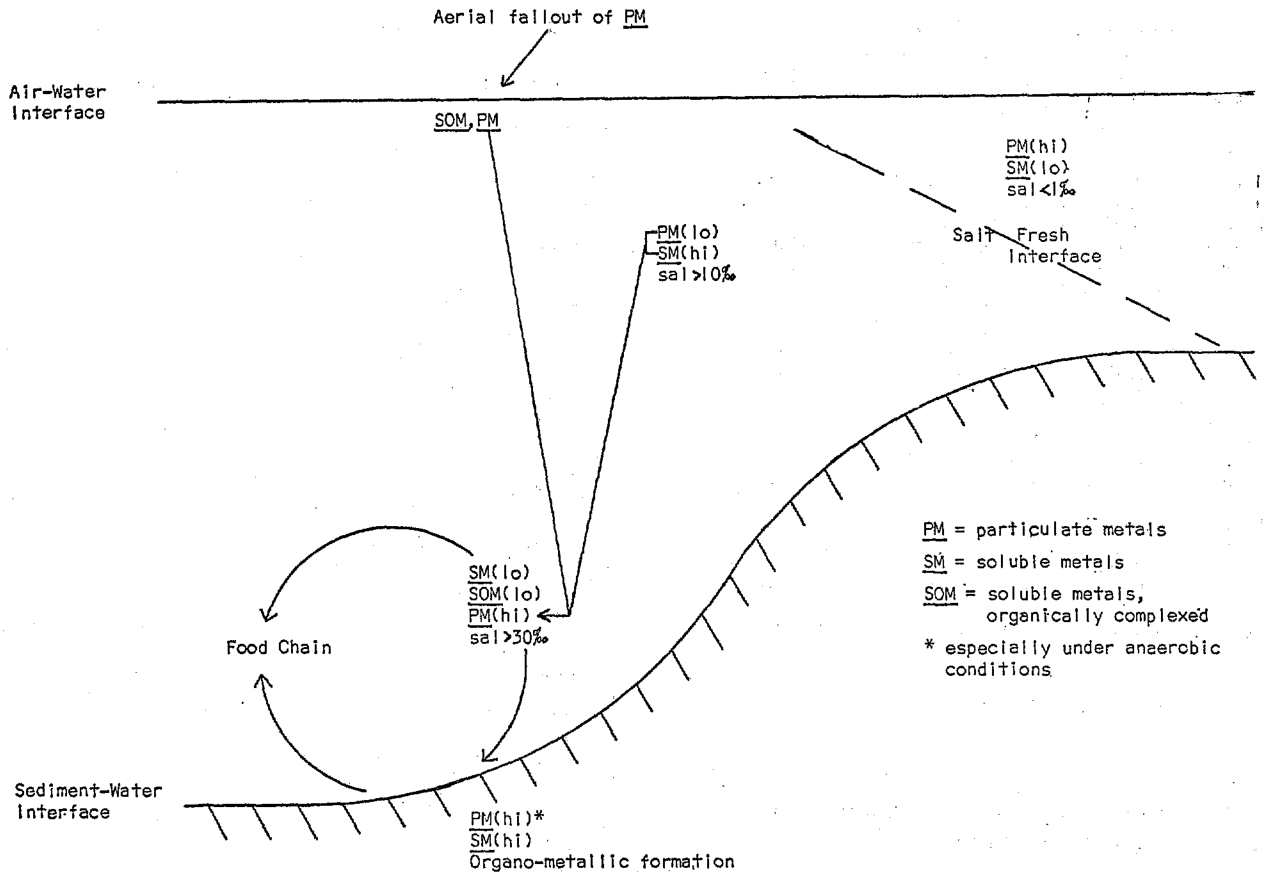

FIGURE 1.—Generalized diagram for sites of metal concentration and transformation of metal forms in the marine environment.

The possible problems of metals in estuaries is emphasized to illustrate the complexities that surround this problem area. Some aspects of the metal problem are of more direct concern to the welfare of man and estuarine systems than others. In an effort to prioritize and define metal problems in the marine environment a metal matrix has been created.

METHODS AND MATERIALS

Trace elements are essential to all life systems, yet excess amounts are toxic. Also, non-essential elements such as mercury, cadmium, lead, and so forth can be toxicants and bioaccumulated to large quantities to affect organisms within marine food chains, including man. Therefore, a matrix of existing toxicity and body burden data using marine species as one axis and metals as the other has been formulated in order to assess, broaden, and validate the data base needed to establish criteria. The metals matrix helps to point out information gaps, thereby defining research goals; it also provides a basis for comparing metal levels and their modes of application in laboratory studies with levels and pathways defined in the natural environment.

A summary of two metals matrices which were constructed mainly from literature reviews by Ketchum, et al., (1972), and Eisler (1973), more recent additions from the open literature, and in-house experiments performed at the National Marine Water Quality Laboratory (NMWQL) are presented in Tables 1 and 2.

RESULTS

The metals matrix indicates that we have information on only 36 elements and of these only 18 have toxicity data listed and of the 18 perhaps only four (Cd, Cu, Hg, and Zn) are sufficiently documented to formulate good criteria. Since the NMWQL has had to respond to unexpected requests for elemental toxicity and bioaccumulation data, in order to anticipate future requests, we have undertaken an in-house program to develop acute and chronic marine bioassay information on a wide spectrum of elements.

However, because combinations of marine biota

Table 1.—Matrix of elements versus marine biota response

Element	Environmental Oceans Clean	Spp. (Phyla) Tested	Organism	Most Sensitive Level	Response
Aluminum	0.01	4 (3)	Redfish	88*	Death
Antimony	0.0005	2 (2)	Algae	3.5	Inhib. cell div.
Arsenic	0.003	6 (4)	Copepod	0.1	72hr LC_{50}
Beryllium	0.0000006	1 (1)	Mummichog	0.0001	Decr. enz. act.
Cadmium	0.0001	34 (7)	Oyster	0.015	Slow sex. devel.
Chromium	0.000005	13 (5)	Algae	0.0001	Decr. culture yield
Cobalt	0.0001	1 (1)	Copepod	0.01	72hr LC_{50}
Copper	0.003	48 (9)	Diatom	0.001	Inhib. growth
Germanium	0.00006	2 (1)	Diatom	1.0	Inhib. growth
Gold	0.000004	1 (1)	Pinfish	0.069	Death
Iron	0.0013	1 (1)	Diatom	0.027	Cell clumping
Lead	0.00003	14 (7)	Ciliate	0.15	Inhib. growth
Manganese	0.005	2 (2)	Oyster	16.0	LC_{50} of embryos
Mercury	0.00003	43 (8)	Oyster	0.0056	48hr LC_{50} of embryos
Nickel	0.002	17 (4)	Algae	0.0002	Inhib. growth
Selenium	0.0004	5 (2)	Copepod	0.01	96hr LC_{50}
Silver	0.00004	9 (5)	Copepod	0.0033	72hr LC_{50}
Yttrium	0.003	1 (1)	Oyster	0.001	Abnormal larvae (98%)
Zinc	0.01	28 (8)	Annelid	0.05	Abnormal larvae

* All concentrations expressed in mg/kg.

versus elemental compounds exist in infinite variety, a number of elements can be eliminated from consideration in the following categories:

1. Elements such as mercury with sufficient information for good water quality criteria.
2. Major constituents of seawater, s.a. Na, Mg, Cl, S04.
3. Major constituents of marine organisms, s.a. C, H, N, O.
4. Noble gases, i.e. He, Ne, et cetera.
5. Elements which are short half-life isotopes.
6. Rare earths.

The remaining, approximately 50 elements, can be listed in priority according to the following considerations:

1. Known toxicity to man.
2. Information indicating elemental impact in the marine environment.
3. The form of the element in seawater.
4. No information available.

It must also be recognized that it is not necessarily the total amount of a metal present in seawater or marine sediments but the form of the metal which may be important to consider with respect to its effects on marine biota. Metals in seawater can be operationally characterized as particulate (metals associated with particles larger than 0.45μ) or dissolved ($< 0.45\mu$). Dissolved metals can be categorized further as inorganically associated, organically bound, i.e. chelated, or metal-organic compounds. Dissolved metal forms are likely to interact with most marine biota; however, the effects may differ if the metals are organically bound. If a metal such as copper is chelated, there may be a reduction in metal toxicity response by organisms such as marine phytoplankton; whereas, if the metal is an organometallic like methyl-mercury, this compound is more toxic than the inorganic form and can also be concentrated in food chains. Particulate metals, probably occurring in high levels near industrial outfalls or ocean dumping activities, are likely to affect filter feeding organisms which ingest and concentrate particulate matter. Consequently, the form of the metals may be the dictating factor in the response of marine biota to heavy metals.

Table 2.—Matrix of elements versus marine biota bioaccumulation

Element	Spp. (Phyla) Tested	Organism	Level Reached	Toxic to Man
Aluminum	7 (1)	Phytoplankton	5000*	−
Antimony	42 (10)	Octopus	0.92	+
Arsenic	88 (12)	Squid (gills)	198	+
Barium	3 (1)	Phytoplankton	262	−
Beryllium	1 (1)	Phytoplankton	8.4	+
Bismuth	1 (1)	Phytoplankton	7.7	+
Cadmium	136 (12)	Abalone (digest. gland)	1162.7	+
Cerium	16 (5)	Fish	64	−
Cesium	20 (6)	Algae	0.64	−
Chromium	30 (4)	Zooplankton	260	+
Cobalt	34 (7)	Zooplankton	110	−
Copper	101 (8)	Squid (liver)	15,160	−
Gold	3 (1)	Mollusc	282	−
Iron	73 (8)	Annelid	42,800	−
Lanthanum	4 (2)	Fish	57	−
Lead	102 (7)	Algae	3100	+
Manganese	51 (5)	Algae	226	−
Mercury	198 (15)	Algae	7400	+
Molybdenum	5 (3)	Zooplankton	36	−
Nickel	45 (6)	Zooplankton	480	−
Plutonium	38 (7)	Algae	21,000 (CF) #	+
Polonium	1 (1)	Fish	61 pCi/gm wet wt	+
Rubidium	6 (3)	Algae	2.3	−
Ruthenium	11 (7)	Sponge	10,000 (CF)	−
Samarium	15 (3)	Annelid	3.6	−
Scandium	20 (4)	Annelid	26.4	−
Selenium	11 (5)	Octopus	71	+
Silver	18 (4)	Squid (liver)	1044	−
Strontium	18 (5)	Algae	4160	−
Thorium	5 (3)	Octopus	9.2	+
Tin	2 (2)	Phytoplankton	101	−
Titanium	6 (2)	Phytoplankton	940	−
Uranium	1 (1)	Fish	21	+
Vanadium	6 (2)	Pteropod	290	−
Yttrium	2 (2)	Mollusc	1000 uCi	−
Zinc	130 (10)	Mollusc	99,220	−

* All values in mg/kg, except where noted.
\# CF—concentration factor.
Toxic to Man: + yes; − no.

On the basis of these considerations, elements are chosen for short-term, acute bioassays. Acute bioassays involve a rapid response of a single species to increasing concentrations of a toxicant. The results of the acute bioassay are reported as the median tolerance limit (TL_m or TL_{50}) which signifies the concentration of toxicant that kills 50 percent of the organisms within a specified time span, usually in 96 hours. Organisms for acute bioassay are being selected from a wide range of representative marine phylla and growth stages.

Elements having low TL_{50} are in turn chosen for long-term chronic bioassays. Chronic bioassays involve a continuous exposure to a sublethal concentration of the toxicant. In the chronic bioassay, any biological response, such as reduction of growth or reproduction, behavior change, histopathological change, et cetera, can be used to monitor effects. Also, test organisms are analyzed to determine possible bioaccumulation of the element which could in turn indicate a potential pathway back to man.

DISCUSSION

A definite need exists to carefully inventory all natural and manmade element sources which might impact the marine environment. Table 3 is a generalized inventory. Assessing potential ocean pollutants, Robinson, et al., 1974, have presented an extensive and important approach for budgeting pollutants; however, the report deals only with the metals iron, copper, and plutonium and concludes that plutonium is the only element of potential global pollution. Similar assessment should be made for all elements; however, these assessments should be focused at more localized areas, such as coastal or estuarine areas as well as on a global scale. These inventories would highlight elements of major environmental concern which should be carefully bioassayed in the laboratory. Also, these budgets should point out specific areas of high metal impact in the United States.

Field investigations of metal impacted areas throughout the U.S. are necessary in order to determine the extent, fate, and effects of metals on marine biota. Have metals per se directly or indirectly caused environmental damage and, if so, to what extent? What are the inputs, rates, routes, and reservoirs of metals within impacted areas? Special consideration should be given to areas of:

1. Mining activities.
2. Smelters.
3. Industrial outfalls, especially metal plating industries.
4. Sewage outfalls.
5. Desalinization plants.
6. Offshore ocean disposal areas for industrial wastes, sewage sludge, and dredge spoils.

Table 3.—Inorganic chemicals to be considered as pollutants of the marine environment.

Element	Natural conc in sea water $\mu g/l$	World production metric tons/year (1968)	Routes of entry into the sea	Pollution categories
H (acids)	pH = 8 (alk = 0.0024)	?	D,A	III c
Be	0.001	250	U	IV c ?
Ti	2	1,000,000	A ?	IV b ?
V	2	9,000	A	IV a ?
Cr	0.04	1,500,000	R(U)	IV c ?
Fe	10	480,000,000	D,R	IV c
Cu	1	5,000,000	D,R	IV c
Zn	2	5,000,000	D,R	III c
Cd	0.02	15,000	A,R	II c
Hg	0.1	9,000	A,R	I b
Al	10	8,000,000	D,R	IV c
CN	—	?	D,R	III c
Pb	0.02	3,000,000	A,R	I a
P	—	?	D	IV c
As	2	60,000	D	II c
Sb	0.45	60,000	U	IV c
Bi	0.02	3,800	U	IV c ?
Se	0.45	1,000	U	III c ?
F	1,340	1,800,000	D,R	IV c ?

D dumping, A through atmospheric pollution, R through rivers (runoff) or pipelines, U unknown.

I–IV order of decreasing menace; a worldwide, b regional; c local (coastal, bays, estuaries, single dumping).

Referenced from FAO Fisheries Reports, No. 99 Suppl. 1. Report of the seminar on methods of detection, measurement and monitoring of pollutants in the marine environment: Inorganic chemicals, Panel 3. Dyrssen, D., C. Patterson, J. Ui and G. F. Weichart.

However, Cross and Duke (1974) have emphasized that it is essential that present efforts be continued and new efforts initiated to determine baseline levels of trace metals in marine organisms and the environmental variables that affect them. These studies should be conducted not only in contaminated environments such as Long Island Sound, New York Bight, and the Southern California Bight, but also in relatively pristine or uncontaminated environments. The concentration of any trace metals can be highly variable both within and between species and influenced by a number of environmental factors. Until we understand the variability that exists in healthy ecosystems, it may be difficult to identify a contaminated ecosystem. Also, because trace metals occur naturally in the marine environment as a result of weathering and volcanic activity, the problem of determining the contribution of anthropogenic additions of trace metals to natural levels in marine organisms is more difficult than with halogenated hydrocarbons or refined petroleum products.

Other questions concerning potential metal pollutants which need to be answered are as follows:

1. Are certain industries, such as power plants, producing excessive metal inputs which should be controlled?
2. Can elemental transformations occur within marine areas to produce more lethal and/or bioaccumulated compounds such as methyl-mercury? If so, which elements are capable of transformation and under what circumstances?
3. Dredge spoils removed from navigational channels are often taken from areas which act as traps for sediments laden with river and estuarine-borne waste. What are the long-term effects of these ocean-dumped dredge materials upon the cleaner shelf areas? How should ocean-dumped materials be handled to lessen environmental impact to disposal areas?
4. Liquid effluents from wastewater treatment plants probably will be a major source of trace metals to estuarine and coastal waters during the next several decades. Efforts should be made to evaluate the impact that these discharges will have on concentrations of trace metals in harvestable marine species that complete a major portion of their life cycle in coastal areas.

According to Schroeder (1973), environmental pollution by toxic metals is a much more serious and insidious problem than is pollution by organic substances such as pesticides, weed killers, sulfur dioxide, oxides of nitrogen, carbon monoxide, and other gross contaminants. Most organic substances are degradable by natural processes; no metal is degradable. Elements in elemental form or as salts remain in the environment until they are leached by rains into rivers and into the sea. Therefore, every effort must be made to slow down the environmental build-up of those elements which are toxic and can cause degenerative diseases.

The solution to problems of metal waste disposal might be expected to be dilution into the vastness of the sea. However, because metals can be concentrated by geological, chemical, and especially biological processes in the sea, the solution to metal disposal problems is not dilution. The solution must be to stop pollution at its source by the development of the proper technology to control and recycle metal wastes. Metal wastes entering the marine environment should be reduced if the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500) to minimize environmental pollutants are carefully enforced.

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POLLUTION IN NATION'S ESTUARIES ORIGINATING FROM THE AGRICULTURAL USE OF PESTICIDES

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ABSTRACT

Estuaries are particularly vulnerable to pollution because they are repositories of wastes which do not come from a point source, such as pesticides. Agricultural pesticides enter the estuarine environment by several means: direct application to water; runoff from treated lands; industrial discharges; domestic sewage; atmospheric drift; and accidental spills. The fish kills in the Mississippi River by insecticides are well known and particularly well documented. Monitoring data have been limited primarily to chlorinated hydrocarbons because of their number, wide use, great stability in the environment, and toxicity to certain forms of wildlife and other nontarget organisms. A recent national survey on organochlorine residues in estuarine mollusks reveals that "at no time were residues observed of such a magnitude as to imply damage to mollusks." However, residues were large enough to pose a threat to other elements of the biota through recyling and magnification. The maximum pesticide residues can be correlated with proximity of monitoring stations to agricultural runoff. Long-term, sublethal effects of pesticides in estuaries are difficult to assess at present, as most data on pesticide effects are limited to a few species and concentration that is lethal in short-term tests under laboratory conditions. Pesticide pollution in the estuarine environment can be minimized through the use of alternative pesticides, more effective use of pesticides, removal of pesticides from water, improvement of farm management practices, regulatory control of pesticide use, and a better understanding of the pesticide behavior in the estuarine ecosystem.

INTRODUCTION

The ocean's biological productivity is largely concentrated in the coastal zone, from the rivers seaward to the salt marshes, the bays, and estuaries. Productivity is high here because basic nutrients, the minerals and organic material washed down river from land, feed plants and animals at the base of the marine food chain. By weight, about a thousand times more food is caught or harvested from the coastal zone than from the open sea. To put it another way, most fish and shellfish are caught within sight of land. Some 70 percent of the valuable sport fish depend on estuaries for their survival. Like all wildlife, marine animals establish themselves where conditions for life are most favorable—plenty of food, areas for spawning, and freedom from predators.

Estuaries are particularly vulnerable to pollution for two reasons: (1) their natural populations are in delicate balance and thus are easily upset by pollutants, and (2) they are the repository for most of a river's pollution load as the river meets the estuary, slows down, and releases its wastes.

The most difficult pollution control problem—for estuarine and coastal waters—is posed by wastes which do not come from a point source, such as pesticides from runoff and drifts, and fertilizers spread on fields. They find their way into streams and rivers and eventually the estuaries and oceans in ever larger amounts. Some argue that these pollutants are even more dangerous to estuarine plants and animals (including man) than municipal and industrial wastes.

Synthetic organic pesticides when used properly have been of tremendous benefits to man and his environment, but when misused or carelessly used, they cause considerable harm. Fortunately, the adverse effects have so far been relatively minor in comparison to the beneficial role that pesticides have played, and most likely will continue to play in the production of food as the world's supply of raw agricultural products continues to decline in proportion to increasing population.

During recent years the overall use patterns of pesticides have changed considerably. The risk or hazards of using pesticides have increased with the sharp rise in their consumption by agriculture, households, industry, and government. Today, more than 34,000 products made from one or more of 900 chemical compounds are currently registered by the U.S. Environmental Protection Agency (EPA) for use in the environment.

Pesticides are poisons; they can present an immediate danger to the user if applied improperly or without sufficient knowledge of their toxic effects. In addition, potential future hazards to human health and other living forms can be created by residues from long-lived pesticides that build up in the food chain.

CURRENT PESTICIDE USE IN THE ENVIRONMENT

Except for 1969 and 1970 when there were slight declines, sales of synthetic organic pesticides in the United States have increased every year since 1963 (Table 1). In 1972, the latest year for which figures are available, production was 1,158 million pounds. The volume of sales that year was 1,022 million pounds, and the value of these sales was $1,092 million. The volume and value of producers' sales were the highest of any year for which records are available.

"Pesticides Review 1973," published by the U.S. Department of Agriculture, provides information on the calculated domestic use at the producers' level for pesticides (Table 2). It is interesting to note that, following a general decline in recent years, DDT in 1972 was up nearly 78 percent over 1971. The sharpest decline in 1972 was made by 2,4,5-T which dropped 64 percent. Use of 2,4-D declined over one-fourth in 1972; however, the use of the aldrin-toxaphene group of pesticides increased by nearly one-fourth that year.

It is predicted that the use of pesticides will continue to increase and the sales value was expected to reach $1.4 billion in 1974 (Figure 1). One reason for this optimism is that acreage devoted to the major field crops accounting for most of the total U.S. pesticide use will be increased by 6 percent that year. The five major crops (corn, cotton, rice, soybeans, and wheat) account for approximately 75 percent of the total pesticide use in the United States. Moreover, with prices of all farm crops at or near all-time highs and yields per acre moving up steadily, farmers will have more money available to spend on pesticides, even after allowing for higher prices. (Chemical Week, v. 114, no. 4, January 23, 1974). Additionally, the demand for farm products is growing rapidly worldwide. Since the farmer is the major supplier of farm products in world trade, he will need more pesticides to meet the growing demand.

Table 1.—Synthetic organic pesticides: Production and sales, United States, 1963–72[1]

Year	Quantity	Change from previous year	Value [2]	Change from previous year
	1,000 pounds	Percent	1,000 dollars	Percent
		Production		
1963	763,477	4.6	444,046	3.9
1964	782,749	2.5	473,815	6.7
1965	877,197	12.1	576,787	21.7
1966	1,013,110	15.5	716,362	24.0
1967	1,049,663	3.6	959,260	34.1
1968	1,192,360	13.6	1,028,469	7.2
1969	1,104,381	−7.4	953,592	−7.3
1970	1,034,075	−6.4	1,058,389	11.0
1971	1,135,717	9.8	1,282,630	21.2
1972[3]	1,157,698	1.9	1,344,832	4.8
		Sales (domestic and export)		
1963	651,471	2.8	369,140	6.6
1964	692,355	6.3	427,111	15.7
1965	763,905	10.3	497,066	16.4
1966	822,256	7.6	583,802	17.4
1967	897,363	9.1	787,043	34.8
1968	959,631	6.9	849,240	7.9
1969	928,663	−3.2	851,166	0.2
1970	880,914	−5.1	870,314	2.2
1971	946,337	7.4	979,083	12.5
1972[3]	1,021,565	8.6	1,091,708	11.5

[1] Includes a small quantity of soil conditioners.
[2] Value of production calculated: unit value x quantity; sales value as reported by the Tariff Commission.
[3] Preliminary.
Tariff Commission, Chemical Division, "Synthetic Organic Chemicals, United States Production and Sales."

Table 2.—Pesticides: Domestic disappearance at the producers' level of selected kinds, United States, 1967–72[1 2]

Pesticide	1967 [3]	1968 [3]	1969 [4]	1970 [4]	1971 [4]	1972 [4]
	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds	1,000 pounds
Aldrin-toxaphene group	86,289	38,710	89,721	62,282	85,005	105,980
Calcium arsenate	2,329	1,992	2,117	2,900	2,457	1,751
Copper sulfate	85,274	87,452	99,840	77,344	70,272	72,214
DDT	35,757	28,253	25,756	20,457	13,234	23,546
Lead arsenate	6,152	4,747	7,721	5,860	4,142	5,024
2,4-D	66,955	68,404	49,526	46,942	32,174	23,179
2,4,5-T	15,381	15,804	3,218	4,871	1,389	498

[1] Disappearance for all domestic uses, including all nonagricultural and chemical intermediate uses. Includes any exports by firms other than producers.
[2] Includes military shipments abroad; these are not considered exports.
[3] Year ending September 30.
[4] Year ending December 31.
Calculated from data supplied by the chemical industry, Tariff Commission, and Bureau of Mines.

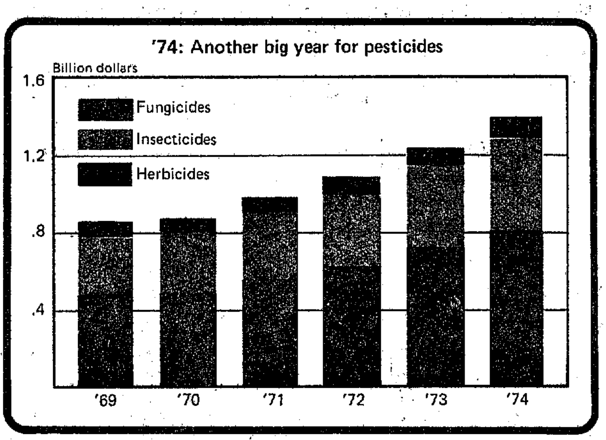

FIGURE 1.—Pesticide sales, 1969–1974. Source: Chemical Week. v. 114, no. 4. January 1974.

Obviously, as the production and use of pesticides continue to increase, the potential for environmental contamination becomes more prevalent.

ROUTES OF PESTICIDE ENTRY INTO THE AQUATIC ENVIRONMENT

Pesticides can become widely dispersed in the environment, mainly by the action of wind and water. Naturally, the most significant residues have been found in and near the areas of intensive use, but traces have also been found as far away as the Antarctic (Tatton and Ruzicka, 1967; Peterle, 1969).

Contamination of the aquatic environment by pesticides has been of public concern for the last two decades. The compounds most frequently incriminated are the organochlorine insecticides: DDT, TDE, endrin, heptachlor, aldrin, dieldrin, chlordane, toxaphene, and lindane. There is little doubt that DDT and, to a lesser extent, dieldrin have been the major contaminants. Traces of these chemicals can be found in almost all compartments of the world's ecosystem. Rivers, streams, lakes, estuaries, oceans, and bottom muds are major reservoirs for these pesticide residues. These pesticides reach aquatic environments through many routes (Edwards, 1973; Reese et al. 1972; Nicholson, 1970; Nicholson and Hill, 1970; U.S. Dept. of HEW, 1969).

Direct Application to Water

Many organic pesticides are applied directly on water to control aquatic weeds, non-game fish, and aquatic insects. Most of these applications are made for a particular purpose and the amount of pesticide used is closely controlled. To minimize undesirable side-effects, these operations are generally managed by professionals. However, control of the amounts used may be lax in massive applications (e.g., emergency mosquito control). In some instances, nontarget species may be very adversely affected.

Post-use dissipation is an extremely important factor in the application of herbicides for the control of aquatic weeds in irrigation and drainage canals, river banks and ditch banks. Most of the herbicides registered for use in aquatic situations have water use restrictions which require at least partial dissipation of the herbicide before normal water use is resumed (Timmer et al. 1970). The pathways of dissipation are almost as varied as the chemicals themselves. For example, volatilization is the most important means for the dissipation of aromatic solvents and acrolein. Adsorption processes predominate in the dissipation of herbicides such as diquat, paraquat, and possibly endothal. Biological and chemical degradation processes account for much of the disappearance of 2,4-D, silvex, dichlobenil and other herbicides.

Runoff and Sediment Transport

Runoff from terrestrial applications is generally considered as the major route of pesticide movement into the water environment. Intensive studies have demonstrated that runoff is probably the single most widespread and significant source of contamination (usually less than 1 ppb) of surface water (Nicholson, 1970; Nicholson and Hill, 1970). Terrestrial application of persistent pesticides also results in their being directly carried into surface waters and, through adsorption on silt and debris, transported into rivers and eventually estuaries.

During runoff the pesticide may be adsorbed on eroding soil particles, suspended in the runoff water, or both. Pesticides of low persistence naturally would have lower runoff than persistent ones. Chlorinated hydrocarbons, because of their persistence and low solubilities in water, are usually transported on the soil particles.

Soluble pesticides enter surface waters dissolved in the water runoff and drainage from the land. However, most of the pesticides reach the water with sediments washed from the land. The chlorinated hydrocarbons have been found extensively in surface waters, and in bottom sediments at 126 locations in the Mississippi River. The deposits are assumed to come from agricultural usage (Barthel et al. 1969).

Organic phosphates are generally more soluble than the chlorinated hydrocarbons. Herbicides, particularly the inorganic types, are highly soluble in water. The greatest danger from the runoff of soluble pesticides is in the period immediately following their application and prior to their becoming adsorbed onto soil particles. To some degree, this condition is under control in the major agricultural areas since weather conditions are closely observed and, to some extent, control the time of pesticide application. The same, however, cannot be said for household application.

Atmospheric Transport

Atmospheric transport to the aquatic environment can be due to (1) drift of pesticides applied aerially, (2) volatilization of the pesticides from the terrestrial environment, and (3) wind erosion.

Direct drift has been found to occur from spraying operations, especially when using aerial application (Frost and Ware, 1970). Fallout from aerial pesticide application is a principal source of water contamination (Spencer, 1971; Goldberg et al. 1971). High levels of atmospheric contamination by pesticides (DDT, toxaphene, parathion) were measured in agricultural areas such as Dothan, Ala.; Orlando, Fla.; and Stoneville, Miss. Higher pesticide levels were found when pesticide spraying was reported than when no spraying was in progress. Only p,p′-DDT and o,p′-DDT were found in the atmosphere at all nine sampling localities, in both urban and agricultural areas. Levels are highest in the agricultural areas of the South, and are generally lower in urban areas (Stanley et al. 1971).

Volatilization is a major pathway for loss of applied pesticides from plant, water, and soil surfaces (Spencer et al. 1973). It has been shown that nearly half the amount of DDT applied to the surface of the soil in field conditions may volatilize, thus making a slow, long-term contribution to the atmosphere (Lloyd-Jones, 1971). Volatilization of a pesticide depends on many other factors, such as air velocity, pesticide concentration, pesticide vapor pressure, temperature, relative humidity, soil water content, and bulk density of the surface soil (Igue, 1970).

Pesticides can be transported by wind and deposited in water far from an area of application; they are now considered to be universally present in the air. Their distribution to sites removed from application areas depends on prevailing patterns of wind circulation and deposition rates. The European-African land area was regarded as the source of chlorinated hydrocarbon insecticides found in airborne dust at Barbados (Risebrough et al, 1968). The insecticides (absorbed on the dust) were carried some 3,600 miles (6,000 km) by the transatlantic movement of the northeast trade winds. Recently, several studies have also presented evidence that the trade wind system of the Atlantic region may deposit amounts of chlorinated hydrocarbons comparable to those transported into the sea by major rivers (Sepa and Prospero, 1971; Bideleman and Olney, 1974; Gaskin et al. 1974).

Industrial and Municipal Wastes

Industrial waste constitutes perhaps the second most significant source of pesticides in water. The wastes from manufacturing and formulating plants, unless very closely controlled, contain pesticides. Additionally, the effluents from plants that use pesticides in their manufacturing processes may contain various amounts of pesticides. The distribution of DDT residues in *Emerita analoga* (Stimpson) along coastal California was recently investigated (Burnett, 1971). The findings showed that aquatic organisms near the Los Angeles County sewer outfall contained over 45 times as much DDT as those near major agricultural drainage areas. The probable source of this high concentration of DDT in the sewer outfall was thought to be a plant that manufactures DDT. This suggests that historically the buildup of residues in California coastal marine organisms could be attributed, to a significant degree, to industrial waste discharge rather than merely to extensive agricultural usage.

Pesticides can also enter water along with municipal wastes, such as sewage effluents. A 1971 review of pesticide monitoring programs in California prepared by an Ad Hoc Working Group of the Pesticide Advisory Committee to the State Department of Agriculture reported that substantial quantities of pesticides, mainly chlorinated hydrocarbons, have been discharged to surface waters through municipal and industrial waste discharges. The quantities of waste waters discharged were so large that even low concentrations of pesticides in water could result in a large emission. The report indicated that if large emissions from the Los Angeles County sanitation districts' outfalls have been occurring for a number of years, this one source may overshadow all other sources of DDT in southern California marine waters.

Effluents from sewers of large urban centers may contain small amounts of pesticides originating from home use but the great magnitude of discharge does not allow this source to be overlooked. It is significant to note that as much as 25 percent of the pesticides in the San Francisco Bay waters, amounting to 4,000 pounds per year, enter the bay through municipal and industrial wastewater discharges.

Researchers at the University of Georgia Marine

Station studied the effects of estuarine dredging on toxaphene concentrations of the marine biota (Durant and Reimold, 1972). Results indicated that, in the estuary, the sediments near a toxaphene plant outfall in Terry Creek, Brunswick, Ga., were found to be contaminated with toxaphene approaching 2,000 ppm, and oysters collected two miles from the outfall were found to contain residue levels near 6 ppm. In a later study Reimold and Durant (1974) found that the monitoring of dredge spoil, fauna, and flora showed toxaphene concentrations to be higher during dredging than before or after. The concentrations in oysters ranged between 2.0 and 5.0 ppm. The eastern oysters, reported to be the best biological monitors, did not demonstrate large changes in toxaphene content resulting from the dredging. A report released by the Georgia Marine Science Center in 1973 discussed the effects of toxaphene contamination on estuarine ecology. It indicates that as the toxaphene content in the plant effluent decreased during the 3-year study period, the toxaphene content of fauna, flora and sediments decreased also. This reflects in part the pollution abatement practices initiated at the toxaphene production plant which greatly reduced the quantities of toxaphene in the plant effluent (Reimold, Adams and Durant, 1973).

Accidents and Spills

Accidents and spills occur during storage, packaging, transport, disposal, and application and may be very serious because of the usually highly concentrated chemicals. Although they may affect only a localized area for a short period of time, the possibilities are almost unlimited and much needs to be done to bring this unintended entry of pesticides into the aquatic environment under control.

On August 11, 1974, parathion, a highly toxic organophosphorus insecticide, and dead fish were discovered in the Yuma main canal, that city's source of drinking water. Fortunately, none of the poisoned water reached the city treatment plant before the accident was discovered. No injuries or death were reported, but the California Fish and Game Department estimated 10,000 fish were killed. Authorities said they were unable to determine how the insecticide was put into the canal (San Francisco Chronicle, Tuesday, August 13, 1974).

FISH KILLS

Fish mortalities result from a variety of causes, some natural and others man-induced. Fish kills brought about by man may be attributed to municipal or industrial wastes, agricultural activities, transportation operations, and other projects such as water manipulations that significantly alter the quality of the aquatic environment.

Fish are significant indicators of water quality. When fish die in large numbers at one time, it is usually a sign of an unnatural phenomenon within the aquatic environment. The destruction of fish not only indicates a severe problem occurring in the water environment, but reduces a natural resource of recreational and often economic value.

The Environmental Protection Agency (EPA) publishes an annual report on fish kills caused by pollution since 1961. This report is the result of cooperative teamwork between EPA, state pollution control agencies, and private citizens. It includes reports of fish kills where water pollution is known or suspected to be the cause of death. Since numerous kills resulting from pollution go unnoticed or unreported, the report cannot be considered complete. Despite these gaps, the data compiled in these annual reports provide useful and basic information, serve to point out potential pollution problems, and alert officials and the public itself to the need for stricter safeguards to keep dangerous substances out of the nation's water resources. In the 1972 report, for the first time since inception, every state in the Union participated.

Table 3 contains a 10-year (1963-1972) fish kill summary by source of pollution. The 17.7 million fish killed in 1972 brought the cumulative total of all fish reported killed by water pollution since 1963 to 225 million. While there was a 76 percent decrease in fish reported killed in 1972 compared to the record 73.6 million fish killed in 1971, the year 1972 was the fifth highest year in the number of fish reported killed.

Industrial pollution was identified as the largest killer of fish during the 10-year period. About 85.5 million (38 percent) fish died from this type of pollution. Municipal operations, which handle wastes from cities, ranked second in the total number of fish killed—60.4 million or 26.8 percent. Unknown operations, a new classification added in 1971 to include fish kill which cannot be linked to a specific pollution source, accounted for 39.1 million (17.4 percent) of the fish kill. This resulted from 219 reported incidents resulting in approximately 35.3 million fish killed in 1971 alone. Agricultural operations ranked fourth, and were responsible for the killing of 17.5 million (7.8 percent) fish. The fifth ranking category—other operations—accounted for the death of 17.3 million (7.7 percent) fish.

Table 4 provides a 10-year summary of fish kill by subcategories of the agricultural operations. It

Table 3.—Fish kill summary by source of pollution (No. of fish killed)

Year	Agricultural	Industrial	Municipal	Transportation	Other Operations	Unknown	Total
1963	560,967	2,690,601	914,379	78,388	100,912	2,471,283	6,816,530
1964	1,415,092	12,525,301	3,893,687	22,211	13,423	—	17,869,714
1965	1,390,136	3,763,948	5,911,604	306,810	20,941	—	11,393,439
1966	1,259,599	4,622,790	1,347,248	102,631	1,410,569	—	8,742,837
1967	1,607,267	8,087,091	643,304	143,123	638,266	—	11,119,051
1968	375,548	6,255,713	6,791,464	825,365	578,124	—	14,826,214
1969	6,293,880	28,680,182	1,155,027	2,057,030	2,450,909	—	40,637,028
1970	1,809,541	9,588,949	6,601,845	465,005	3,820,994	—	22,286,334
1971	1,023,337	4,652,392	24,798,432	664,180	7,257,478	35,257,226	73,653,045
1972	1,807,555	4,694,390	8,360,594	456,526	1,028,869	1,369,284	17,717,218
Total	17,542,922	85,561,357	60,417,584	5,121,269	17,320,485	39,097,793	225,061,410
% Total	7.8%	38.0%	26.8%	2.3%	7.7%	17.4%	100%

Source: Data extracted from "Fish Kills Caused by Pollution" series, published annually by the U.S. Environmental Protection Agency.

shows that pesticides comprised the leading source of agricultural pollution, with 11.4 million (64.9 percent) fish fatalities. Reports of fish kills under pesticides include incidents in which spraying machinery and pesticide containers were cleaned or dumped into nearby streams, lakes, or estuaries. However, the majority of reported incidents resulted from pesticides being washed into water by rainfall after spraying for agricultural purposes.

Fish kills by type of water are summarized in Table 5. For the period 1963-1972, approximately 60 percent (134.5 million) of the total reported fish were killed in freshwater, while 37 percent (83.4 million) fish fatalities occurred in estuary-type water. In 1971, about 77 percent (56.4 million) of the total reported fish were killed in the estuary-type water, and for the first time since the annual report system started in 1960, more fish were reported killed in estuarine waters than in freshwater. The large kill in 1971 was primarily due to a number of large kills totaling 31.4 million fish which were reported in two localized areas—Escambia Bay, Fla., and Galveston Bay, Tex. It should not be interpreted as a national trend. The number of fish reported killed in estuary water in 1972 decreased appreciably from the number reported in 1971. Nevertheless, the significant increase of fish kills in the estuaries since 1968 is of great national concern since estuaries serve as breeding and nursery grounds for many species of marine fish.

MONITORING OF PESTICIDES IN RIVERS AND ESTUARIES

Reports of insecticide residues in streams and rivers in the United States began to appear about 10 years after the introduction of organochlorine insecticides and it soon became obvious that small amounts of these insecticides occurred in many waterways. At present, all of the different organochlorine insecticides have been reported from U.S.

Table 4.—Fish kill summary by agricultural operations (No. of fish killed)

Year	Pesticides	Fertilizers	Manure-silage Drainage	Total
1963	401,415	1,400	158,152	560,967
1964	191,167	67,040	1,156,885	1,415,092
1965	770,557	2,697	616,882	1,390,136
1966	217,406	1,200	1,040,993	1,259,599
1967	329,130	10,000	1,268,137	1,607,267
1968	325,194	15,116	35,238	375,548
1969	5,982,877	73,569	237,434	6,293,880
1970	1,409,794	4,069	395,678	1,809,541
1971	264,504	65,760	693,073	1,023,337
1972	1,500,147	30,944	276,464	1,807,555
Total	11,392,191	271,795	5,878,936	17,542,922
% Total	64.9	1.5	33.6	100

Source: Data extracted from "Fish Kills Caused by Pollution" series, published annually by the U.S. Environmental Protection Agency.

Table 5.—Fish kill summary by type of water (No. of fish killed)

Year	Fresh	Salt	Estuary	Total
1963	5,478,130	1,234,300	104,100*	6,816,530
1964	15,334,099	2,531,700	3,915	17,859,714
1965	11,255,658	102,121	35,660	11,393,439
1966	8,698,607	19,050	25,270	8,742,927
1967	11,086,012	30,000	3,039	11,119,051
1968	9,869,851	1,888	4,954,475	14,826,214
1969	34,956,048	641,150	5,039,830	40,637,028
1970	11,991,099	536,000	9,759,235	22,286,334
1971	15,205,913	2,014,914	56,432,218	73,653,045
1972	10,669,294	37,766	7,010,158	17,717,218
Total	134,544,711	7,148,889	83,367,900	225,061,500
% Total	60	3	37	100

Source: Data extracted from the "Fish Kills Caused by Pollution" series published annually by the U.S. Environmental Protection Agency.
*"Brackish water."

rivers, sometimes in large quantities. DDT has been found in the largest amounts, but it is not always the most common residue, although some rivers have contained it in all the sampling programs. There have been relatively few reports of residues of chlordane, endosulfan, and toxaphene in U.S. waterways, although these are commonly used in the U.S. Since 1962, there have been surveys of pesticides in most of the major waterways. A National Pesticide Monitoring Network was set up in 1964 as a cooperative effort of the Federal departments making up the membership of the Federal Committee on Pest Control. It was initially designed on the basis of the minimum monitoring needed to establish baseline levels of pesticides in substrates of food, humans, soil, water, air, wildlife, fish, and estuaries and to assess changes in these levels. This program continued until the passage of the Federal Environmental Pesticide Control Act of 1972 (Public Law 92-516) at which time the program received legislative status. The Environmental Protection Agency (EPA) had taken important steps to assure an uninterrupted study of environmental residues and to enlarge and upgrade the program. Additionally, as the focal point of legislative authority, EPA accepted the responsibility of financing several of the large projects by contracts with another government agency having field staff qualified to do the work.

Pesticides in the surface waters of the U.S. for the period 1964–1968 were reported by Lichenberg in 1970. The monitoring was restricted to chlorinated insecticides. It was found that individual insecticides, when present, were in fractions of a part per billion (ppb).

A study entitled "Pesticides in Selected Western Streams" was initiated in 1965 by the U.S. Geological Survey as a contribution to the national program. The period of 1965 through September 1968 is covered by two publications (Brown and Nishioka, 1967; Manigold and Schulze, 1969). In the 1967–1968 period, 62.5 percent of the "whole water" sampled contained no detectable insecticides (minimum detectable level 0.01 ppb) and the remaining had individual pesticide levels only in fractions of a part per billion. The pesticides monitored were rather restricted in number (DDT and its metabolities; aldrin; dieldrin; endrin; heptachlor and its epoxide; lindane; chlordane; toxaphene; endosulfan; phosphorothioates; PCB's; and three herbicides: 2,4-D; 2,4,5-T; and silvex).

During the period 1968–1971 (Schulze, Manigold and Andrew, 1973) compounds found included the common chlorinated insecticides and herbicides. "Heptachlor and its expoxide were not detected during the 3-year period, and aldrin was found only once. DDT was the most frequently occurring insecticide, and 2,4,5-T the most common herbicide. The amounts observed were small; the maximum concentration of an insecticide was 0.46 mg/liter for DDT, and of an herbicide 0.99 mg/liter for 2,4-D . . . Concentrations were highest in water samples containing appreciable amounts of suspended sediments." Pesticide concentrations never exceeded the permissible limits established for public water under the Water Quality Criteria published by the Department of the Interior in 1968, although in several instances concentrations were measured that were above the environmental levels of 0.05 mg/liter recommended for marine and estuarine waters.

Organochlorine insecticides are not usually in solution in water because they are all of very low solubility. Tests on river water emptying into the ocean, even after draining land heavily sprayed with pesticides, may contain relatively low concentrations of pesticides. Yet, in certain conditions, such as during periods of high turbidity caused by sediment load, it seems probable that rivers could carry a heavy concentration of pesticides to the sea. The mud at the bottom of many rivers is heavily contaminated with pesticides and will continue to be a reservoir for periodic future contaminations.

As a part of a study to assess the potential contamination of the San Francisco Bay from chlorinated hydrocarbon compounds, bottom materials from 26 streams tributary to the bay were analyzed for chlordane, DDD, DDE, DDT and PCB residues. These compounds were found in all stream bed samples analyzed, thus illustrating their widespread distribution in the bay. Chlordane was ubiquitous, with a concentration range similar to that of the other compounds (Law and Goerlitz, 1974).

Accumulation of pesticides in bottom sediments plays a very important role in their disappearance from contaminated water. Pesticide concentrations in the sediments may be much higher than the concentrations in the water. Studies in major agricultural river basins in California revealed that an average pesticide concentration of 0.1 to 0.2 ppb in river water may mean that bottom sediments contain 20 to 100 ppb.

It can be expected that rivers would carry pesticides down to the sea so that large amounts of residue could be deposited in estuaries and near the mouth of rivers. However, there is surprisingly meager evidence of pesticide residues in those areas. The report on "Chlorinated Hydrocarbons in the Marine Environment" (National Academy of Sciences, 1971) estimated that "as much as 25 percent of the DDT compounds produced to date may have been transferred to the sea. The amount of DDT compounds in the marine biota is estimated to be less than 0.1 percent of total production, yet this amount has produced a demonstrable impact upon the environment."

It was estimated that 1.9 metric tons of pesticides are carried into the San Francisco Bay annually by the Sacramento and San Joaquin Rivers (Risebrough et al. 1968), and that 10 metric tons reach the Gulf of Mexico each year from the Mississippi River. Although these may seem very large amounts, they are small relative to the pesticide usage in the vicinity of these rivers. These residues represent no more than 0.1 percent of the amounts of pesticides used in the area supplying water to the estuaries, but some may be rapidly taken out to sea because of the strong tidal exchange in the San Francisco Bay (Frost, 1969).

The Estuarine Monitoring Program was organized by the Bureau of Commercial Fisheries in 1965 to monitor the chlorinated hydrocarbon insecticides reaching the major estuaries on the Atlantic, gulf and Pacific coasts. In July 1972, the National Marine Fisheries Service of NOAA withdrew its financial support and EPA took over the responsibility of the entire estuarine study. This study has been redesigned to include marine life in all of the 200 primary estuaries listed in the "National Estuarine Survey."

A recent publication entitled "Organochlorine Residues in Estuarine Mollusks, 1965–72—National Pesticide Monitoring Program" reports the findings covering 15 coastal states during a 7-year period (Butler, 1973). Shellfish were chosen as 'indicator' organisms because they are sessile and readily concentrate pesticides from the environment, yet the chemical is flushed out of their tissues at a uniform rate when the pesticide is no longer present in the environment (Duke, 1970). The findings of this study are summarized as follows:

1. The analyses of 8.095 samples for 15 persistent organochlorine compounds showed that DDT was the most commonly identified pesticide and occurred in 63 percent of all samples analyzed. In most cases, estuarine pollution with DDT was intermittent and at levels in the low parts-per-trillion range. The maximum DDT residue detected was 5.39 ppm.

2. In most estuaries monitored, detectable DDT residues have declined in both number and magnitude in several species of estuarine mollusks in recent years. DDT pollution peaked in 1968 and has been declining markedly since 1970.

3. Dieldrin was the second most commonly detected compound with a maximum residue of 0.23 ppm.

4. Other organochlorine residues (endrin, mirex, toxaphene, and polychlorinated biphenyls) were found only occasionally and generally at low levels, with exception of toxaphene.

The report further points out that "at no time were residues observed of such a magnitude as to imply damage to mollusks; however, residues were large enough to pose a threat to other elements of the biota through the processes of recycling and magnification." It is also of interest to note that 38 samples (0.5 percent) had DDT residues exceeding 1.0 ppm. These samples were collected in California, Florida and Texas in drainage basins having intensive agricultural development.

With regard to California, where approximately 22 percent of the nation's pesticides are sold, the report states:

> DDT residues in mollusks were consistently larger in California than in any other area monitored with the exception of a single station in south Florida. There is a clear pattern of maximum pesticide residues being correlated with proximity of the monitoring station to runoff from agricultural lands. In southern California, where most samples contained typically large residues, residues were consistently higher at Hedionda and Mugu Lagoons, the recipients of agricultural runoff waters, than at Anaheim Slough which receives intermittent runoff from the urban and industrialized sections of Los Angeles. Residues in samples from estuaries draining the intensely cultivated central and southern parts of the state were larger, by one order of magnitude usually, than those in samples collected from watersheds north of San Francisco Bay where dairy land predominates.

A preliminary report regarding the influence of pesticide runoff in Monterey Bay, Calif., points to the Salinas River as the source of pesticide pollution (Haderlie, 1970). This is the only major river entering the Bay, and it drains the 100 mile long Salinas Valley with a drainage area of 4,000 square miles. The Salinas Valley is one of the richest agricultural areas in California, specializing in lettuce, broccoli, celery, sugar beets and so on. During a 10-year period between 1960 and 1969, it is conservatively estimated that 63 tons of DDT were sprayed on the crops and soil of the valley each year. Students at the Hopkins Marine Station near the bay made a study during the late spring of 1969 of the DDT content of the sand-dwelling mole crab, *Emerita*. This animal does not seem to concentrate DDT content in high concentrations. *Emerita* taken from the open coast outside Monterey Bay had too little DDT in their tissue to be measurable, yet *Emerita* taken from sand near the mouth of the Salinas River had DDT concentrations of 0.14 ppm. In addition, it was noted that during the late spring and summer of the same year, more dead seabirds were found along the shore of Monterey Bay than ever before. At one period 440 dead birds were found on one stretch of beach less than a mile long. Of these, 37 percent had been oiled, 14 percent shot, and 49 percent had died of unknown causes. The livers of this third group of birds were subjected to tests for chlorinated hydrocarbons. The dead seabirds contained concentrations of pesticides as high or higher than that recorded anywhere. A brief summary of the data is as follows:

DDE Concentrations in Livers of Dead Seabirds

Brandt' cormorants	107–155 ppm
Western grebes	192–292 ppm
Fork-tailed petrel	373 ppm
Ashey petrel	412 ppm
Ring-billed gull	805 ppm

Although one cannot be certain that it was the high concentrations of DDT residues that killed these animals, circumstantial evidence seems to indicate pesticides as the cause of death.

In an earlier study concerning the chlorinated hydrocarbon pesticides in California bays and estuaries, it was found that pesticide residues in estuaries geographically isolated from agricultural areas seldom exceeded 100 ppb. Pesticide residues frequently exceeded this level in agricultural regions and were found as high as 11,000 ppb in shellfish from polluted areas (Modin, 1969).

A similar study was conducted to investigate the chlorinated hydrocarbon residues in shellfish (Pelecypoda) from estuaries of Long Island, N.Y. (Foehrenbach et al. 1971). Results indicate that the distribution of residues could at times be correlated with agricultural use or type of community in the watershed surrounding the various stations.

EFFECTS OF PESTICIDES ON ESTUARINE ORGANISMS

It is becoming apparent that increased information is necessary about the distribution, concentration, and elimination of pesticides in estuarine areas. Most literature reports on pesticides in estuaries concern chlorinated hydrocarbons such as DDT, endrin, dieldrin, and aldrin. However, the overall picture of the dynamics of these compounds in the estuarine environment is obscure.

Potentially more hazardous are pesticides that persist in the environment and move up in the food chain. For example, small amounts of chemicals adsorbed by plankton and insects are transferred in increasing concentration to fish, birds, animals, and eventually to man. There is evidence that concentrated pesticide residues act adversely on the reproduction and behavior of certain wildlife species and may threaten their survival. In certain instances, pesticide residues accumulated through food chains have been implicated as causing death of contaminated animals. For example, the loss of fish-eating waterbirds at Tule Lake and Clear Lake in California and the reduction of pelican population on the Pacific coast were attributed to pesticides which had traveled through biological networks and accumulated in the bodies of these birds.

Several review papers have recently been published which bear on the subject of pesticides and estuarine organisms. Butler (1971) discussed the influence of pesticides on marine ecosystems; Foehrenbach (1972) described experiments on chlorinated pesticides in estuarine organisms; Whitacre (1972) et al. reviewed the pesticides and aquatic micro-organisms; and Edwards (1973) summarized the literature concerning the persistent pesticides in the environment. Perhaps the most comprehensive review on the subject is the paper written by Walsh (1972) entitled "Insecticides, Herbicides, and Polychlorinated Biphenyls in Estuaries."

Phytoplankton

Phytoplankton probably act as primary concentrators of pesticides in water. There is evidence that these toxicants reduce photosynthesis, but bioconcentration by algae may be more important ecologically because they transfer many materials to higher trophic levels. Under laboratory conditions, algal samples were found to contain dieldrin concentrations ranging from 0.1 to 100 milligram per kilogram dry weight. Algal concentrations of dieldrin were as much as 30,000 times those occurring in the water (Rose and McIntire, 1970). Algae are the primary producers in the aquatic environment. Grazers and higher consumer organisms depend upon algae as a food source, either directly or indirectly.

Extensive pesticide accumulation by select algal communities constitutes a contaminated food source for animals which feed on those forms.

Invertebrates

Organochlorine insecticides are so toxic to aquatic invertebrates that these aquatic organisms have long been used to bioassay insecticides. A more complex problem than that of toxicity is the accumulation of pesticides in various aquatic organisms. When pesticides reach water, they are rapidly adsorbed by the bottom sediment, plankton, algae, aquatic invertebrates, aquatic vegetation, and fish. Such accumulations, often increasing through different trophic levels in aquatic organisms, have been demonstrated experimentally by several workers and are well-known.

Organochlorine insecticides are relatively insoluble in water but seem to have a great affinity for the tissues of aquatic invertebrates. Most of these aquatic organisms seem to contain some residues of these insecticides; the only difference is that those from the more remote areas such as Antarctica seem to contain less than those from more temperate regions closer to main usage areas of these insecticides. Other than this, the amount reported does not seem to differ significantly between organisms that live in freshwater, seawater, lakes, rivers, or estuaries.

Organic particulate matter of estuaries is an important food source for benthic organisms. In areas where most of the primary production occurs through the slow bacterial decomposition of such plant materials as marsh grasses, rushes, and mangroves, a release of pesticide residues to the water may occur. This decaying plant detritus becomes an enriched food source when utilized by other microorganisms. The mud dwelling fiddler crab concentrated DDT residues in its muscle tissues after consumption of detrital food material from sediment (Odum et al, 1969). In the field, DDT residues appeared to be associated with particulates in the range of 250 to 1,000 microns. Because crabs and other detritus-feeding animals consume particulate matters of that size range, the authors concluded that organic detritus particles constitute a reservoir from which the pesticides enter the food chain.

Oysters extract nutrition from the aquatic environment by filtering particles of food from the water which is continuously passed in and out of their bodies. The organisms accumulate pesticide-contaminated particles in this fashion. Oysters efficiently store trace amounts of pesticides and are used as estuarine monitoring organisms by the Gulf Breeze Laboratory of EPA. They provide a sensitive index of the initiation, duration and extent of chlorinated hydrocarbons' pollution in an estuary. The concentration or elimination of residues in oysters is dependent upon the level of pollution, the water temperature, and their position relative to the water flow. To eliminate DDT residues of 150 mg/kg may require three months or longer while residues of less than 0.1 mg/kg may disappear in about two weeks.

Chronic exposure to sublethal concentrations of pesticides can reduce productivity of estuarine fish and shellfish (Butler, 1969). The insecticides DDT, toxaphene, and parathion are toxic to oysters at concentrations of approximately 1 ppm in water. When exposed to only 1.0 ppb of each of these insecticides separately, no effects were noted in young oysters (Loew et al. 1971). The population of marsh fiddler crabs was significantly decreased by treatment of their habitat with abate, an organophosphorus insecticide, according to Ward and Howes (1974). The population decrease may have resulted from sublethal effects which rendered the animals more vulnerable to predators.

The effects of organochlorine insecticides on aquatic invertebrate populations may constitute both direct and indirect hazards to other animals. The most susceptible of these organisms are the smaller crustacea, which are killed by amounts of the order of 1.0 ppm $\times$ 10^3. Still susceptible, but less so, are the larger crustacea.

Invertebrates that are not killed may exhibit a variety of indirect effects of the pesticides, such as loss of coordination and other behavioral symptoms, loss of fertility, or retardation of growth (Edwards, 1973). Considerable changes in the species' habitat structure may occur if predators and their prey differ in susceptibility to these chemicals. All of these effects may greatly influence overall populations of aquatic invertebrates and, since these are a major food source for fish, may exert strong environmental pressure on fish populations. Moreover, the residues in their bodies may accumulate in the tissue of fish and other animals that eat them and in this way exert further environmental stress.

Vertebrates

The literature on residues of organochlorine insecticides in fish is very extensive. One can only consider the subject very generally and select data from some of the recent studies, which should serve to provide a general assessment of current status of pesticide levels in fish and other vertebrates. It is well known that marine fishes contain insecticides and, in general, are less susceptible to poisoning than some other aquatic forms (Table 6).

In general, organophosphorus compounds tend to be more acutely toxic than the organochlorines, and herbicides are less toxic than insecticides (Butler, 1971). Effects of organophosphates may last for only hours or days, whereas the organochlorines are more persistent and exert their effects following bioaccumulation and magnification in trophic pyramids.

Of all the organochlorines, DDT is by far the most common and occurs in the greatest amounts. There

Table 6.—Acute Toxicity (24 hours) of 240 Pesticides to Estuarine Fauna

Pesticide (ppm)	No Effect 1.0 %	Toxic to 20% of Test Population 0.1–1.0 %	0.01–0.1 %	0.001–0.01 %
Fish	46	16	28	10
Shrimp	33	14	33	20
Oysters	41	21	33	5

Source: Butler, 1971

is some evidence that the amounts of organochlorine residues accumulated by fish are influenced by the lipid content of the fish; the more lipid they contain, the less susceptible they are to the pesticide. Similarly, the larger the fish, the greater the concentration of residues they may contain. Hannon et al. (1970) found that fish in the higher trophic levels tended to have a large proportion of the organochlorine residues that they contain in the form of metabolites such as DDE, DDD, heptachlor epoxide, and dieldrin. It has been reported that there were greater concentrations of organochlorine residues in fish from higher trophic levels, even when movement of the residues through a food chain was impossible (Hamelink et al. 1971).

The amount of pesticide in a field population may also vary over the seasonal cycle in different species. Concentrations of DDT in the *Triphoturus mexicanus* taken from the Gulf of California increased with size of the fish (Cox, 1970). The annual variation in the content of DDT and its metabolites in five species of fish from the estuary near Pensacola, Fla., was observed by Hansen and Wilson (1970). They stated that pesticide residues in benthic fishes which remain in one location are better indicators of pollution than residues in pelagic fishes.

Fishes are generally more resistant to pesticides than shrimps and oysters but are more sensitive than other vertebrates to organochlorine pesticides. Fishes do, however, vary in their responses to avoid water containing DDT, endrin, Dursban and 2,4-D. When fish were given a choice of two concentrations of the pesticides, the highest concentration of 2,4-D was avoided, but the highest concentration of DDT was preferred (Hansen, 1969). The author suggested that if the capacity to avoid a pesticide is controlled genetically, fish which survive pollution by this means would produce more offspring with the capacity to avoid the chemical. Thus, genetic ability to avoid pesticides would have survival value for the species. Fabacher and Chambers (1971) found that mosquitofish probably result from other factors in addition to increased lipid content. These may include decreased uptake, "resistant" nervous tissue, stress-tolerance, or others. The total mechanism or resistance is probably a complex interaction of many, many factors.

Organochlorine insecticides in the estuarine environment constitute both direct and indirect hazards to fish and to those organisms that feed on fish. The indirect aspect is that plankton and other fish food may adsorb large quantities of these chemicals, thus poisoning the fish that eat them. Alternatively, when the fish take up residues, they may be affected by them. Many indirect sublethal effects of organochlorine residues on fish have been reported; they include lower disease resistance, sub-normal feeding rates, and reproductive failure, to mention a few. Another hazard caused by pesticide residues in fish results from the fact that these animals are a major source of human food. If residues in fish are large, they may accumulate in man to a possibly hazardous level. In countries with more stringent legislation, these fish would be unsalable as human food. The rejection of fish products because of high concentrations of pesticides, e.g., DDT in California jack mackerel, can pose a hardship to fishermen and an economic burden on governments.

Estuarine Birds and Mammals

Extensive literature exists detailing effects of pesticides on estuarine birds (Moore and Tatton, 1965; Heath et al. 1969; Anderson et al. 1969; Lamont et al. 1970; Lamont and Teichel, 1970). A recent report by Johnston (1974) indicates a decline of DDT residues in migratory songbirds killed when the birds flew into television towers in Florida. The results showed a progressive decline in the concentration of DDT and its metabolites (DDD and DDE) in their fat depots for the period 1964 to 1973. This decline is apparently correlated with decreased usage of DDT in the United States during the same time, according to the author.

Little is known, however, about pesticides in mammals. DDT was found in seals from the Antarctica and in grey seals, common seals, and harbor porpoises in England and Scotland. Pesticides have also been found in whales (Wolman and Wilson, 1970). Blubber of grey whales and sperm whales from waters near San Francisco contained up to 6.0 ppm of DDT.

MINIMIZING PESTICIDE POLLUTION IN THE ESTUARINE ENVIRONMENT

Estuaries are vital nursery and feeding grounds for major commercial fisheries. The possibility that they might act as "a sink for the persistent pesticides" is intolerable (Butler, 1971).

There is little doubt that the persistent pesticides, particularly DDT and dieldrin, are major long-term contaminants of the aquatic environment, and small traces can be found in almost all compartments of our ecosystems. The situation with respect to estuarine pollution from pesticides emphasizes the need for more basic research. Investigations to establish safe limits for toxicants in water cannot be done on a short-term basis. Effective research in this area requires long-term commitment of government agencies and the public at large.

Use of Alternative Pesticides

The main problem of finding alternatives for persistent insecticides is not that suitable insecticides cannot be developed, but is economic, because persistent insecticides can be made and sold so cheaply. Additionally, one dose gives protection against soil pests for several seasons. The recent shift in pesticide usage from the organochlorines to the so-called "substitutes" or "non-persistent" pesticides is an encouraging trend. However, the less persistent substitutes such as organophosphates and carbamates, which are gaining in popularity, are also more toxic to man and certain other non-target organisms. Although there is a considerable knowledge about the residues of these substitutes and about their metabolism in target organisms, little is known about their overall effects on our aquatic environment.

Metcalf et al. (1972) demonstrated the possibilities of producing selective and biodegradable analogues of organochlorine insecticides using a model ecosystem for the evaluation of pesticide biodegradability and ecological magnification (1972a). Metcalf (1972b) emphasized that the principle of selectivity and biodegradability must be included in the future development of better pesticides if we are to begin to solve the many problems of human ecology and environmental pollution arising from pest control.

The use of biological agents is promising. Two bacterial pesticides are now commercially available and have registered with EPA—*Bacillus popilliae* and *B. thuringiensis*. These insecticides have a number of important advantages. They effectively control specific insects, do not harm humans, livestock, fish, wildlife, and beneficial insects, and do not damage plants. Furthermore, insects do not become resistant to these control agents. On the other hand, the bacterial insecticides are not as fast-acting as most conventional chemical insecticides. Usually, bacterial insecticides are a more expensive means of insect control. And poor weather conditions may prevent proper control.

Better Use of Pesticides

Many of the pesticide problems that have arisen through the use of persistent pesticides are due to careless use as well as unnecessary use of chemicals. Too often, large areas of land have been indiscriminately sprayed to control forest insects, mosquitoes, or agricultural pests. Aerial sprays fall on all parts of an ecosystem. Such spraying operations should be severely limited, even with non-persistent pesticides. A notable example is the disastrous effect on aquatic animals resulting from the use of mirex to control fire ants in the southeast United States. This pesticide is highly persistent in the natural environment and has been shown to be moderately carcinogenic when injected in laboratory mice. Subsequent long-term studies have demonstrated chronic toxic effects on crabs and shrimp. A national survey of oysters and other shellfish demonstrated that mirex is the fourth most commonly found pesticide residue. It was also reported that mirex contaminates shellfish in estuarine drainage areas of southern states.

New formulations are now available to slowly release pesticides at the time needed. Recently, EPA granted final label approval for the first commercial marketing of a microencapsulated pesticide, Pennwalt Corp's Penncap-M, which consists of a suspension in water of polyamide microspheres containing methyl parathion. Such formulation offers a promising approach to achieving more efficient, more economical, safer, and more controlled use of pesticides.

Integrated Pest Management

In recent years, the concept of integrated pest management has been re-emphasized. The goal is to bring the best of all available control techniques to bear against pest problems rather than to rely solely on chemical pesticides. Its strategy is one of "management and containment" rather than "seek and destroy." This method combines the intelligent manipulation of natural control techniques with the essential use of pesticides; it has been successfully applied in several parts of the world. In Israel, effective programs have been set up against citrus pests; in California for pests on cotton, alfalfa and grapes; and in central Europe for pests in orchards.

Removal of Pesticides

Runoff from agricultural land is an important source of pesticides in rivers and estuaries. Controlling such runoff through good soil conservation practices would substantially decrease the contamination of water. In regard to industrial and municipal discharge, efforts should be made to increase the efficiency of extraction of pesticides from the water and other detoxification processes such as microbial degradation and energetic radiation (ultraviolet or gamma ray).

Better Understanding of Estuarine Ecosystems

There is an urgent need for detailed and extensive studies on the effects of pesticides in the estuarine and marine environments. Only with additional scientific data will a sound estuarine management policy be possible. Immediate attention is required to clarify the effects of environmental variables on the acute toxicities of pesticides to sport and commercial fishes as well as on their effects on various elements in the food web. In addition to laboratory results, information is needed on toxicity under natural conditions. For example, what effects do water chemistry, temperature, biota, and many other environmental factors have on toxicity? What is the significance of the size, age, and condition of the fish? This information is essential if sound predictions concerning the biological effects of pesticides are to be made.

Little is known about the long-term, sublethal effects of pesticides on fishes or other aquatic organisms. To gather information requires prolonged exposures of fishes to variable concentrations of the toxicant in question.

Much information is needed on the manner in which an "unstressed" estuarine system operates before one can properly assess the impact of a pesticide or other chemicals on such systems.

The interactions of the various communities with each other and with their physical environment could be affected by a pesticide. One way to quantify such effects is to construct an experimental ecosystem in which several species of organisms and their substrates can be subjected to the pesticide (Duke, 1974) to obtain information on rates, routes and reservoirs of accumulation. Once a satisfactory compartmental model is developed, substituting different data enables the impact of different variables to be evaluated.

Governmental Control of Pesticide Use

On October 21, 1972, the President signed into law H.R. 10729, the Federal Environmental Pesticide Control Act of 1972 (Public Law 92-516), amending the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1947. All provisions of the Act must be in effect by October 1976. The new act, FIFRA as amended, extends federal registration and regulation to all pesticides, including those distributed or used within a single state. It requires the proper application of pesticides to insure greater protection of man and the environment.

The FIFRA was administered by the U.S. Department of Agriculture until the authority was transferred to the Environmental Protection Agency (EPA) when it was established in December 1970. EPA has the authority to cancel a pesticide registration if it was later determined that the directed use of the pesticide posed a serious hazard to man or the environment. EPA also can suspend a pesticide registration and stop interstate shipments immediately. Unlike cancellation, suspension orders can be initiated only when the products present an "imminent hazard."

Within the last few years EPA has taken several control actions against a number of persistent organochlorine pesticides. In 1971 EPA initiated cancellation proceedings under FIFRA against DDT, mirex, aldrin, and dieldrin. After extensive hearings, the agency announced cancellation of nearly all remaining uses of DDT in June 1972, based on potential future hazard to man and his environment. The agency has also limited the use of mirex against the imported fire ant in the southeastern United States, primarily because of hazard to aquatic life.

On August 2, 1974, EPA issued suspension notices for aldrin and dieldrin, citing evidence of "imminent hazard." On October 1, 1974 EPA administrator Russell Train ordered an immediate suspension of further production of aldrin and dieldrin, because of evidence they may cause cancer. This order became final on May 27, 1975 when EPA Chief Administrative Judge H.L. Perlman announced that the U.S. Court of Appeals for the District of Columbia had ruled that aldrin and dieldrin create "imminent hazards" when used.

On November 26, 1974, EPA gave notice of its intent to cancel all registered uses of heptachlor and chlordane which are now in widespread use for home, lawn, and garden pest control. Their major agricultural use is on corn crops. On July 30, 1975, EPA ordered an end to the manufacture and sale of the two pesticides, citing an imminent human cancer hazard and the available substitute pesticides now registered with EPA. However, this suspension order allowed continued production of these two pesticides for termite control by ground insertion and the dipping of roots and tops of nonfood plants.

In 1971 and 1972, EPA issued suspension and cancellation notice for mercury pesticides. A variety of organic mercury compounds are used in agriculture as fungicides and in the paper industry as slimicides. If they find their way into the aquatic environment they are readily converted under anaerobic conditions to methyl-mercury compounds, which are very readily taken up by aquatic organisms and accumulated in the food chain.

SUMMARY

Trends in the production and use of pesticides in recent years indicate that there will be an increased demand for pesticides during the next decade due to the mounting demand for food and the need to reduce the devastation of food supplies by insects, weeds, and diseases. According to a World Health Organization estimate, about a third of the agricultural products grown by man worldwide are consumed or destroyed by insects. There is little doubt that pesticides will continue to play an important role in the production of food.

The most difficult pollution control problem—for estuarine and coastal waters—is posed by wastes which do not come from a point source, such as pesticides from runoff and drift. Agricultural pesticides enter the estuarine environment through their direct application to water, runoff and sediment transport from the treated fields, atmospheric transport, industrial and municipal waste discharge, accidents and spills.

Fish kills in the United States are well known. Agricultural operations ranked fourth in the total number of fish killed, and pesticide was the leading source of agricultural pollution, with 11.4 million fish fatalities between 1963 and 1972. In 1971 about 77 percent (56.4 million) of the total reported fish kill occurred in the estuary-type water. The significant increase of fish kills in the estuaries since 1968 is of great national concern since estuaries serve as breeding and nursery ground for many species.

Monitoring data have so far been limited primarily to chlorinated hydrocarbons, because of their number, wide use, great persistence in the environment, and toxicity to certain wildlife and non-target organisms. At present, all of the different organochlorine insecticides have been reported from U.S. rivers and estuaries, sometimes in large quantities. Although these residues do not seem to present immediate danger to fish and shellfish, they were large enough to pose a threat to other elements of the estuarine ecosystem through recyling and magnification. Present monitoring data indicate that maximum pesticide residues can be correlated with proximity of monitoring stations to agricultural runoff.

Long-term sublethal effects of pesticides in estuaries are very difficult to assess at the present time, as most data on pesticide effects are limited to a few species and concentrations that are lethal in short-term tests under laboratory conditions. It is only, perhaps, in regard to the persistent organochlorine pesticides, DDT and dieldrin in particular, that more information is available concerning their behavior in the aquatic environment. It is now relatively easy to determine the concentration of a wide variety of organochlorine pesticide residues in estuarine and marine samples. It is, however, much more difficult to establish the significance of the residues either at the species or community level.

Health hazards to man arising from pesticide pollution in the estuarine environment have resulted from the persistence of pesticides in water, bioaccumulation in estuarine food chains, and some localized contamination of the coastal waters. Depending on the chemical nature of the pesticide and its biological behavior, the health hazard to man may be of an acute nature for people exposed locally or the result of chronic low level exposure of the general population from ingestion of contaminated food. Critical assessment of the ultimate health hazards of individual pesticides requires an adequate knowledge of their behavior in the estuarine ecosystem, their pathways through the dynamic system existing in the estuaries, and their fate in terms of accumulation or transformation. It is also necessary to have quantitative data for each of the various stages through which a pesticide passes before it finally comes in contact with the human organism. As in other areas of toxicological research, there is the added difficulty of extrapolating experimental studies in animals to man in order to measure the probable hazards to man.

Recent regulatory actions taken by the Environmental Protection Agency have placed a near total ban on domestic use of DDT, aldrin, dieldrin, heptachlor, and chlordane. Undoubtedly, for many years to come, these persistent chemicals will continue to be detectable in the estuarine environment due to seasonal flooding and the resuspension of estuarine sediments.

Pesticide pollution in the estuarine environment can be minimized through the use of alternative pesticides, more effective use of pesticides, removal of pesticides from water, improvement of farm management practices, and a better understanding of pesticide behavior in the estuarine ecosystem.

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THE IMPACT OF OFFSHORE PETROLEUM OPERATIONS ON MARINE AND ESTUARINE AREAS

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ABSTRACT

American is facing a serious energy crisis, as domestic petroleum supplies are consumed at a greater rate than new reserves can be located and placed in production. It is necessary to the nation's economic and political security to expand the search for crude oil and natural gas into the frontier areas of our Outer Continental Shelf. Expertise gained through more than two decades of exploration for and production of crude oil and natural gas in the Gulf of Mexico, and the advances in exploration, drilling and production technology and equipment, minimize the danger of environmental damage from offshore petroleum operations. Studies of the impact of oil on the marine and estuarine areas are continuing, and the results so far indicate that petroleum operations can be and are being conducted in an environmentally acceptable manner.

INTRODUCTION

A great deal of misunderstanding exists concerning the impact of petroleum operations on the biological, economic, and environmental sectors of the marine and estuarine areas. This misunderstanding, in turn, has led to public concern, particularly in light of proposed expansion of offshore petroleum industry activities following the energy crisis.

It would be naive—and inaccurate—to suggest that a significant expansion of exploratory, production, transportation, and refining activities would be without some impact on shore and near-shore life. But it would be equally naive—and inaccurate—to suggest that such impact as would occur would be all negative, or that any impact, per se, would be intolerable from an environmental point of view.

There is clearly an urgent need to not only protect and sustain the viability of our estuaries, but to develop secure domestic petroleum reserves as well. Our economic and political structure was visibly shaken by the 5-month embargo of Arab crude oil and products refined overseas from Arab crude, and by the fourfold increase in the cost of imported oil imposed by the Organization of Petroleum Exporting Countries.

THE NATION'S ENERGY MIX

Petroleum, that is, crude oil and natural gas, provides this nation with 77 percent of its current energy requirements. Crude oil supplies 46 percent; natural gas, 31 percent. Our heavy dependence on petroleum is the product of many factors, not the least of which have been—and continue to be—environmental considerations.

In the case of coal, which currently provides 18 percent of the energy market, environmental restrictions have played a major role in limiting production. Bans or severe restrictions on the use of the more economical mining methods, as well as sulfur emission control standards—some of which go far beyond the need to protect national health and safety—have greatly hampered moves to increase coal production and use. This has been an important factor in increasing demand for petroleum, as an alternate fuel in manufacturing and electrical power generation.

Further demand has been placed on petroleum by the seemingly interminable delays in trying to site and construct nuclear power generating plants, and in allowing onstream operations of existing facilities. While technological problems have caused some of these delays, environmental considerations were at the base of many delays—and, in some cases, cancellations—of nuclear plant construction. Thus, despite the rosy future predicted for power from nuclear reactors during the 1950's and '60's, less than 2 percent of U.S. energy is now derived from nuclear generators.

A similar fate has befallen potential hydroelectric power plant construction. Virtually every attempt to develop a new hydroelectric power site is blocked by environmental opposition. The few remaining sites for hydropower installations have—for all practical purposes—been ruled out of consideration by environmental activities.

Thus, we have been left with a growing dependence on oil and natural gas as the suppliers—at least for the next 10 to 15 years—of our nation's energy. Continued reliance on potentially insecure and high cost foreign oil, however, is not a practical solution to our energy problems. The economic consequences of over-dependence on imports—both from a security and balance of payments aspect—should have been indelibly engraved on the public conscience in the aftermath of Winter 1973–74 and in the outflow of U.S. dollars in 1974.

Yet, if we are to keep even our present level of productivity—much less increase our industrial activities to meet the needs of an economic upswing—U.S. imports of crude and refined oils must temporarily continue. There is no viable alternative, just as there is no viable alternative to increasing our domestic exploration and production activities. Only increased availability of petroleum will permit the nation to buy the time needed to develop alternate energy sources.

There is, on the horizon, the vision of a number of self-renewing, non-polluting energy sources. These include—but are not limited to—ocean, tidal and wind power, geothermal energy, nuclear fission, and solar power. Prototype facilities and/or laboratory models exist for some of these energy alternatives. But it will be a number of years—perhaps into the next century—before they become economically feasible. Time, however, is the critical factor. For all practical purposes, petroleum is the only major energy source with the proven technology capable of producing sufficient fuel to tide this nation over until alternate energy sources become reality.

The United States Geological Survey estimates that the remaining total petroleum resources of the United States, discoverable and recoverable under today's technology and economics, may range as high as 189 billion barrels of oil and 1,094 trillion cubic feet of natural gas. The onshore potential, however, appears less readily recoverable than the potential of the Outer Continental Shelf (OCS). The larger, more readily located onshore areas are believed to have been found and placed into production. The primary locations for additional onshore resources are thought to lie at greater depths and in undeveloped hostile areas. Thus, the need to search out the oil and natural gas deposits of the OCS assumes greater importance.

OFFSHORE PETROLEUM EXPLORATION AND PRODUCTION

The United States Geological Survey has estimated that the discoverable, recoverable petroleum resources of the OCS may range from 10 billion to 49 billion barrels of crude oil and 42 trillion to 181 trillion cubic feet of natural gas. By geographic area, these deposits are thought to be within the following estimated probability range:

Offshore Area	*Crude oil (in billions of barrels)*	*Natural gas (in trillions of cubic feet)*
Atlantic	2–4	5–14
Gulf of Mexico	3–8	18–91
Pacific	2–5	2–6
Alaska	3–31	8–80

Development of this potential becomes all the more expedient in light of the almost steady decline in the ratio of U.S. proved reserves to production, stemming, for the most part, from governmental interference in the fuels marketplace. U.S. domestic production peaked in the early 1970's. And it will be several years before that situation begins to be reversed by the flow of oil from Alaska's north slope, increased production through secondary and tertiary recovery methods, and new production from existing, but not fully developed, fields. Nevertheless, the master key to petroleum security rests firmly in unlocking the as yet undiscovered potential of our Outer Continental Shelf.

Petroleum exploration and production from marine areas is not an experimental undertaking. As far back as the late 1890's, underwater drilling was a fact of life in California, where piers were extended into the water to support drilling and production facilities. However, modern drilling and safety technology had its origin in petroleum operations in the Gulf of Mexico, with drilling starting in earnest following World War II.

To date, more than 19,000 wells have been drilled in the U.S. marine environment. And, in fact, nearly 17 percent of all domestic oil and 19.5 percent of our natural gas production in the U.S., today, comes from offshore activities.

Yet, despite the headlines which would indicate otherwise, there have been only four significant oil spills from drilling and production operations in our offshore areas. And none, not even the much-publicized spill in the Santa Barbara Channel in 1969, caused permanent ecological damage.

Since that spill, marine exploratory and production technology has improved greatly. Both industry and governmental specifications have undergone significant upgrading to decrease oil spill potential. Safety equipment, monitoring techniques, and personnel training in spill prevention and cleanup have advanced. The capability of the industry to minimize environmental damage has been substantially enhanced.

EFFECTS OF OIL ON MARINE BIOTA

Quite frankly, prior to the Torrey Canyon accident off the Cornwall Coast of England, and the Santa Barbara spill about two years later, there had been little investigation of the fate of oil in the environment. Such is no longer the case. While much is yet to be learned in this area, a number of facts have evolved from existing research.

In May 1969, a series of studies—part of a multimillion dollar research program—was initiated by the American Petroleum Institute. These studies were designed to develop scientific answers to questions surrounding the fate of oil in the marine environment and its biological impact. The studies have been and are being conducted by some of the nation's leading universities and independent research laboratories. Research contracts have been awarded to such institutions as the University of Southern California, University of Maryland, Texas A & M University, Scripps and Woods Hole Institutions of Oceanography, Battelle Northwest and Battelle Columbus Laboratories, Exxon Research and Engineering, and the Bermuda Biological Station.

The petroleum industry, through the API program, wanted to find out, for example, answers to these questions: What happens to oil in the sea; how much is evaporated, goes into solution, is physically dispersed; what are the mechanisms that brought about these changes; and what are the effects of climatic, oceanographic, meteorological, and chemical influences on oil in the sea.

The studies sought answers to: biodegradation processes and how they vary as a function of climate, bacterial composition and distribution, nutrient uptake, and seasonal variation. The effects of oil on the food chain have been studied, including the impact on organisms at the egg, larvae, juvenile, and adult stages, and on their subsequent generations. Questions as to the effect of dispersants superimposed on an oil-polluted biosystem have been considered. Bioassay data on No. 2 fuel oil, various crude oils, and residual fuel oil were sought, including the retention, concentration, and depuration of such oils by marine organisms. Finally, the industry wanted to determine the immediate and long-term effects of an oil spill, and how this differs from chronic oil pollution sustained by persistent natural seepage.

At this early date, all of the results of this ambitious research program are not in. However, the facts that have evolved—coupled with other investigations throughout the world—confirm certain data and put to rest certain myths and speculations. These known facts are:

1) The fate of oil and its immediate and long-term impact depend upon a highly complex interrelationship of physical, chemical, and biological factors. These include evaporation, dispersion, flushing, dissolution, photo oxidation, littoral deposition, sedimentation, accumulation, microbial oxidation, and last, but most important, organism uptake. In the majority of spills, winds, currents, and tides rapidly dilute or disperse the oil below toxic concentrations.

2) Oil is ingested by marine organisms, such as shellfish, shrimp, and finfish. The effects depend on the particular species, its stage of growth, and the amount and kind of oil ingested. Recent uptake and depuration studies have been conducted by the Battelle Northwest Laboratories in Puget Sound, at the Texas A & M Marine Research Laboratory in Galveston, and at the Scripps Institution of Oceanography in California. Admittedly, laboratory studies have their limitations when it comes to predicting the effects of oil on organisms in the real world. Nevertheless, the results of such studies have confirmed that marine organisms do accumulate petroleum hydrocarbons, but once placed in an oil-free environment, the organism quickly discharges the ingested oil. For example:

(a) At Texas A & M, brine shrimp were found to absorb and purge aromatic hydrocarbons in a matter of hours. No metabolization of the oil fractions occurred.

(b) At Scripps, however, three different species of fish were found to detoxify these hydrocarbons by metabolizing them in the liver and excreting the byproducts in their urine.

(c) At the Battelle Northwest Laboratories, Pacific oysters that had assimilated oil were found to depurate the hydrocarbons within a few days when returned to an oil-free environment.

(d) In the Plymouth Laboratory in England, the spider crab *Maia squinado* was found to rapidly detoxify and excrete naphthalene.

3) Biological damage to an ecosystem depends upon such factors as: the type of oil spilled, biota

of the area, the dose of oil, the physiography of the area, the season, weather conditions, previous exposure of the area to oil, exposure to other pollutants, and treatment of the spill.

4) Three conditions must prevail for damage to occur from a spill: (a) a refined oil must be involved; (b) the volume of oil spilled needs to be large with respect to the receiving body of water; and (c) storms or heavy surf must thoroughly mix the water, oil and sediments in the area.

5) Crude oil constituents, especially the volatile aromatics—naphthalenes and olefins—which have a low boiling point, are far more toxic than are the remainder, and are more soluble in water. Fortunately, these lighter constituents quickly evaporate, so that the risk is a short-term one.

6) Certain polynuclear aromatics, such as 3,4 benzpyrene, are potential carcinogens. Some of them occur in crude oil in minute quantities. It has been postulated that these carcinogenic polynuclear aromatics are assimilated by marine organisms and are concentrated as they are passed up through the food chain to man. There is no evidence, however, that abnormal growths, either tumors or cancers, in man or marine organisms result from oil spilled in the marine environment and subsequently transferred through the food chain. Another team of scientists, who did their research on the Sargasso Sea ecosystem, found that petroleum hydrocarbon concentrations were essentially constant throughout the food chain. Polynuclear aromatics, incidentally, are produced by vegetation and phytoplankton in large quantities, and are, moreover, biodegradable.

7) Refined oil, such as No. 2 fuel oil, is generally more toxic than crude oil. When massive amounts of such oil inundate coastal areas for sustained periods of time, extensive damage to marine fauna can occur and complete restoration may take years. Fortunately, such episodic spills are rare.

8) No spill, not even the most severe (e.g. Torrey Canyon, West Falmouth, and the Tampico Maru), has resulted in any permanent damage to the environment. In most spills, biological recovery is achieved within a few generations, involving less than one year.

9) Only about 20 percent of the more than 100 spills classified as "major," that occurred between 1960 and 1971, resulted in sizeable seabird mortality. According to one study, for other forms of marine life, damage was described as extensive in approximately 15 percent of the spills. In several of the spills, damage to marine life was caused by the misuse of highly toxic dispersants. Such dispersants have now been largely replaced by nontoxic substitutes.

10) Low levels (10–100 ppm) of oil dispersant emulsions can, under laboratory conditions, reduce primary productivity of marine phytoplankton and its production of chlorophyll *a*. Oil dispersant emulsions at a level of less than 1 ppm, however, have a stimulatory effect on the phytoplankton resulting in an increase in the mean productivity rate.

At such low concentrations, oil is a nutrient—a source of carbon. When flagellates are exposed to highly toxic water-soluble oil concentrations for 24 hours, their growth rate and production of chlorophyll *a* is virtually stopped. When transferred to a fresh medium, they resume normal growth rates (1 to $1\frac{1}{2}$ generations each 24 hours) and chlorophyll *a* production within three to four days. Only a relatively small number of flagellates need to survive to repopulate rapidly a given area after a spill.

11) Salt marsh grasses, when exposed to oil, will recover very quickly, especially if no detergent treatment is undertaken and repeated oilings do not occur.

12) With rare exceptions, oil spills do not cause death to free swimming finfish. Such fish evidently sense the presence of oil and swim clear of the slick. However, fish that swim near the surface, such as pipe fish and capelin, would be most susceptible; those found at intermediate depths, such as shiner perch, would be less susceptible; and those inhabiting the water column near the bottom, such as flounder and sculpin, would be least susceptible.

13) In general, an organism is more susceptible to oil at the larval stage than at the juvenile stage; and the juvenile stage is more vulnerable than the adult stage. There is always an exception to the rule. It is found that the least susceptible stage for brown shrimp is the post-larval period of life.

14) Chronic and acute exposures to oil in laboratory tests have not resulted in any growth inhibition in brown shrimp or oysters.

15) The health of a marine community in the immediate vicinity of a natural oil seep was comparable to the health of a similar (control) community far removed from seepage areas.

These, then, are some of the facts that are surfacing from studies of the impact of oil on the marine environment. Many more questions and myths remain to be clarified. They will require thorough and dispassionate studies. Such work is ongoing, not only by the oil industry and the federal government, but by state and private laboratories throughout the world.

OFFSHORE OIL SPILLS STUDIES

The widely circulated charges of massive and permanent damage to nearshore and estuarine life resulting from petroleum exploration, drilling, and production operations offshore have, to a large extent, been generated out of fear of the unknown, and nurtured by non-factual information from a host of instant experts on the effects of spilled oil. This was made particularly clear at the time of the Santa Barbara spill. And, unfortunately, the disproved charges are still repeated from time to time in the media.

The facts concerning the damage from that spill are readily available, the results of two independent scientific studies of the area. The first, by the Allan Hancock Foundation of the University of Southern California, noted that, while there was some loss of life among certain species of the Channel's flora and fauna attributable to the spill, other factors present in the area at the time of the spill contributed significantly to the mortality rate. Among these contributing factors were:

- For centuries, crude oil has been entering the Santa Barbara Channel from natural seeps (natural seeps off Coal Oil Point, for example, exude from 11 to 160 barrels of crude oil daily into the sea);
- In winter (as when this particular spill occurred) marine life in the channel is at a low ebb—a seasonal factor unrelated to pollution; and
- The worst floods in 40 years had taken place just prior to the spill, placing sealife under extraordinary stress from freshwater runoff, storm debris, sewage, sediment, and pesticides.

The Allan Hancock Foundation study, based on on-site observations and comparisons to pre-spill data, found that, of the 18,000 birds in the channel at the time of the January 1969 spill, 3,500 to 4,000 birds died from all causes. By May, seasonal migration had brought the bird population up to 85,000. Only isolated traces of oil remained buried on the beaches a year after the spill. Damage to the biota was not widespread, but was limited to several species; and the area has recovered well. The channel fish catch was actually found to have increased in a 6-month period following the oil spill, compared to the year-earlier period. Despite the claims of some people at the time of the spill, the incident had no apparent effect on whales and seals.

Commenting on the Santa Barbara spill, a scientist at the California Institute of Technology (which was not a party to the 40-man investigation by the Allan Hancock Foundation) concluded, "There is one unavoidable fact—all animals are reproducing now in the Santa Barbara area."

While marine operations have been undertaken over a longer period of time in the California offshore area, operations in the Gulf of Mexico have been significantly greater, both in exploration and production. More than 16,000 oil and gas wells have been drilled in Gulf of Mexico waters . . . without damage to the fish population.

The commercial fish catch in the gulf increased from 571 million pounds in 1950 to 1.5 billion pounds in 1973, according to the U.S. Department of Commerce's National Marine Fisheries Service, while the value of the commercial fish catch rose from $50.4 million to $268 million—an increase of 432 percent. During the same period, the percentage of the total commercial fish catch in the U.S. taken from the Gulf of Mexico rose from 12 to 33 percent. Most of this increase is attributable to improved fishing techniques and the taking of menhaden (a formerly non-commercial fish). However, the increase does indicate that petroleum operations in the area have not decreased the commercial fish population.

Sport fishing has actually improved in the area of the oil platforms. The platforms provide a foundation for the growth of sea plants and invertebrates, thereby creating the first step in the food chain. About a dozen or more species of fish virtually unknown in the area prior to drilling operations have been recorded near the rigs. Many of these fish are believed to have been brought to the installations by ocean currents as eggs or fry, and remained to mature under the favorable food and cover conditions created by the platforms.

Shrimp landings from the Gulf of Mexico, in 1973, accounted for almost one-half of the total U.S. shrimp catch (182.1 million pounds out of the 372.2 million pound total), and for 79 percent of the total value of the U.S. shrimp catch. And the National Marine Fisheries Service reported marked production increases in hard blue crabs taken from the gulf in 1973.

In reference to the effects of oil spills from marine platforms in the gulf, Dr. John G. Mackin, professor emeritus of biology, Texas A & M University, has concluded that they have had little harmful effect on the area's marine life. Dr. Mackin has studied the inshore and nearshore Gulf of Mexico ecology and marine communities extensively since 1947. His view is supported by Dr. Lyle St. Amant, assistant director, Louisiana Wildlife and Fisheries Commission, who stated recently—in connection with marine operations in Louisiana gulf waters: "We cannot detect any harmful effects on fish."

In-depth studies of the effect of petroleum offshore operations, over an extended period of time, can and do provide vital information on changes in the marine community. Too often, however, other information is presented which lacks the necessary foundation for accurate conclusions. Baseline studies, which fail to extend through a continuum of seasons and fail to cover a number of cycles, frequently result in questionable data. For example, a baseline study provides a reference point for a particular area at a particular time. A second baseline study taken later—without the benefit of a continuous history of environmental events—would provide a similar reference point for its area and point of time. The interstitial, unrecorded events, however, could so distort the differences as to make comparisons of little value.

A temporary gyre moving through the water column—or a number of other ephemeral events—could significantly alter the benthic marine community, perhaps leaving a permanent change in the biota of the area. If unrecorded for want of the baseline continuum, the conclusions drawn from the change in the benthic community might easily—and erroneously—be assigned to other causes, for example, a later recorded oil spill, invalidating the results of the more recent baseline study.

PREVENTION AND CONTROL OF OIL SPILLS

The petroleum industry has expended a great deal of effort, time, and money on oil spill prevention through employee training courses and sound maintenance programs. Even with these continuing efforts, some risks remain. Accordingly, the industry has also taken the initiative in developing the means to minimize spills that do occur.

The harbor cooperative has been one of the results of industry efforts to increase response capability. The form of these cooperatives varies with the needs and location; the object, however, is to pool the funds and/or equipment of companies in a given area, thus significantly increasing their response capability. In some cases, these cooperatives include municipal fire departments, and other local governmental agencies.

There are in existence, or in the planning stage, some 100 harbor cooperatives in the United States. They are located not only on the gulf, east and west coasts, but also on inland lakes and rivers. These include several basic forms of cooperatives: industrywide (oil companies in the area); communitywide (oil companies, other companies, government agencies, and public organizations in an area); and subscription (an experienced local contractor supplying cleanup equipment, materials and key manpower).

For example, one such cooperative—funded by the oil companies searching for energy resources in the Gulf of Mexico—employs a contractor to store and maintain both shallow-water and open-sea equipment in a state of 24-hour readiness.

Included are helicopters, skimmers, booms, communications systems, bird rescue and cleaning materials, and sorbent generating equipment. All can be easily transported by air, land, or water. Fast response equipment is also stored at several strategic locations, enabling on-the-scene activities to begin at a spill as far as 100 miles distant, within 12 hours.

Oil spill cleanup cooperatives have demonstrated their ability to respond promptly and effectively in sheltered waters or in open seas under relatively calm conditions. However, technology for handling spills under heavy sea conditions needs to be further developed. The petroleum industry is committed to expanding its cleanup skills to meet needs wherever they arise, and is continuing its efforts to advance the state of the art through research and experimentation.

Among the projects under study or in developmental process are these: establishing and updating compendiums cataloging information on available sorbents, surfactants, combustion promoters, sinking agents, and biological agents; developing and testing an open-sea oil skimmer; researching methods for protecting shorelines and beaches exposed to oil from spills, using petroleum-consuming microorganisms and polymeric films; and improving training of personnel in the use of techniques and equipment for oil spill cleanup.

Work is also continuing to improve avian protection techniques. Experiments are under way on methods to frighten sea birds away from spill areas, using distress cries and other sonic techniques. And substantial progress has been made in the area of improved rescue and treatment of oiled waterfowl.

The industry feels that the best way to handle oil spills is to prevent their occurrence. To this end, a sophisticated array of hardware and practices has been developed. An indication of the extent of spill prevention techniques and equipment can be found in the following description, although the material mentioned is by no means all-inclusive.

At the well, where prevention begins, automatic shutdown devices are installed as part of the offshore drilling and production program. These devices detect increases and drops in pressure, changes in flow rates, and other production factors. Subsurface valves, for example, close down the flow of oil in event of an accident, malfunction, or other incident at the surface. Master switches are installed which can stop the entire production system, should an emergency threaten life, property, or the environment. Fire detection devices can trigger the emergency shutdown system. For day-to-day operations, drainage and containment systems collect any spillage or waste oil. Other safety devices in common use on marine platforms include navigational aids to warn vessels.

The platforms, themselves, are designed to withstand storms equivalent in intensity to that of the worst storm recorded during a 25- or 100-year period, depending on location. When storms of sufficient intensity to affect drilling occur, all operations cease, and the drilling platform is secured. If the storm is expected to be especially severe, personnel are removed from the platform.

Other measures are taken during daily operations to prevent pollution from petroleum activities. These include the onboard processing of water from wells to remove oils, or the transportation of these liquids to shore for separation processing.

When an oil reservoir is depleted, the wells are plugged with cement to protect underground strata, and to prevent any leakage to the surface. Equipment is removed, and underwater piping is cut off below or at the seafloor, to eliminate any hazard to commercial fishing.

Pipelines play a major role in transporting oil and gas produced offshore to onshore facilities. There is little reason to anticipate increased pollution from this source, because pipelines are constructed to safety standards set forth in strict industry codes and, in the United States, in government regulations. These standards include specifications for design, construction, operation, and maintenance. They make provision for automatic safety alarm systems, shutdown devices, and regular inspections along the lines to check for possible leakage, damaged piping or construction; and, inland, for any watercourse changes that might affect pipe security. The record in oil pipelining has shown it to be the safest and most secure mode of transporting oil.

ONSHORE IMPACTS

A concern closely related to the need for an acceptable environment is the question of onshore development resulting from offshore production of petroleum. The social, environmental, and economic impacts of existing offshore and nearshore production in the Gulf of Mexico and the Santa Barbara area, unfortunately, cannot be used as an accurate gauge of impacts that might be anticipated in the areas adjacent to potential frontier Outer Continental Shelf areas, such as the Atlantic coast. In the Gulf of Mexico, for example, onshore petroleum production development started a number of years before any attempt was made to develop the offshore potential. The first year of recorded petroleum production in the State of Louisiana was 1902, and for Texas, 1889. While drilling in the estuarine areas of Louisiana began in the 1930's, offshore exploration and development began in the late 1940's, with significant activities continuing since that time.

However, several sound projections can be made concerning the impact of petroleum operations along the east coast. First, advancements in the state of the art of petroleum offshore operations will minimize any environmental risks that might be associated with such activities. Additionally, there are in effect today in the United States stringent environmental laws, regulations, and controls that will prevent the construction of environmentally unacceptable support facilities.

Second, the social and economic aspects of Atlantic coast offshore and onshore support operations will be minimized by the nature of the areas nearest the most likely exploration and production activities. Unlike the gulf coast region during the early years of petroleum operations there, industrial complexes already exist along the east coast, for example, the Newport News-Norfolk, Philadelphia-Baltimore, and Greater Metropolitan New York areas. This industry is well-suited to provide many of the requirements anticipated in implementing any Atlantic offshore programs.

Local helicopter services, water transport, shipyards, and other businesses would logically be called upon to provide much of the materials and support needed offshore. And, certainly, the impact on local payrolls, work orders, and employment opportunities would be beneficial. At the same time, roads, schools, and public services are presently in place, significantly lessening any negative impact on government finances from offshore exploratory and development operations.

COASTAL ZONE MANAGEMENT PLANNING

It takes from three to 10 years to bring a new oil or gas field into full production, once petroleum is discovered, if the search turns up commercially significant quantities of petroleum. Add to this time the years required to develop leasing schedules, hold environmental impact hearings and draw up impact statements, hold lease sales and conduct exploration activities, and the time before significant impact could occur is placed into proper perspective.

That time could—and should—be used to develop the coastal zone management plans that would enable orderly and environmentally acceptable support facilities to be built. And that time would also allow for the programming of any governmental services that might be required over the productive life of the reservoirs. Thus, environmental, social, and economic impacts could be anticipated and intelligently accommodated within a logical time frame.

SUMMARY

There is a critical need to develop energy resources in the United States, resources that will protect the political, social, economic, environmental, and military security of the nation. Petroleum—crude oil and natural gas—will be called upon to provide the lion's share of that energy security until alternate energy sources can be developed.

This nation and its people cannot afford the luxury of waiting until our known supplies are exhausted, in the blind faith that new sources will be provided. Rather, we must pursue—in an orderly and expeditious manner—the development of our petroleum potential. The technology exists for such development. And those potential sources of oil and gas can be located and produced with minimal impact on the environment.

While studies continue to evolve even safer methods of petroleum production, and while new energy sources are being researched and developed, we must proceed in the search for secure domestic petroleum reserves. That means opening up new areas to development—both offshore and in the more remote areas, such as onshore Alaska—on a timely basis designed to accommodate the petroleum industry's capability to safely explore and develop leased areas. There is no other viable alternative to such development, if we are to reduce dependence on imported crude oil and refined products.

RESEARCH APPLICATIONS

THE EFFECT OF ESTUARINE CIRCULATION ON POLLUTION DISPERSAL

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ABSTRACT

This paper gives a brief review of different types of circulation in estuaries, how they act to disperse pollutants, and to what extent the dispersion process can be modeled by existing analytical, numerical, and hydraulic models.

INTRODUCTION

One important feature of estuaries is their ability to assimilate wastes and transport them to the ocean. It is possible, by adequate mixing with the receiving water, to discharge a larger quantity of waste into an estuary than into the rivers that feed it, while still meeting a given receiving water standard, because in addition to the inflow of river water the estuary contains a continuous circulation of water from the ocean to help with dilution. Pollution in an estuary, or more precisely the concentrations of undesirable materials, depends on two things: the quantity and makeup of the waste discharges, and the rate of flushing. In general, the flushing rate increases towards the ocean end. At the landward end the only flow available for flushing is that of upland rivers, but the closer one approaches the ocean the more recirculated ocean water is available to increase the flushing rate and decrease the concentration of wastes. Temperature, also, is affected by the flushing rate; except, close to the source discharges of warm or cold water are diluted in the same way as other wastes.

This paper discusses how flushing rates can be quantified, predicted, and used as part of the process of specifying allowable waste loadings. First, in section II, we discuss the various mechanisms which, in concert, drive the circulation of ocean water. Section III describes a practical analysis for computing flushing rates, while section IV describes procedures that can be used in a more predictive way, but are still in a state of research and development. Section V discusses both practical needs relevant to current legislation and longer-term research needs.

TYPES OF CIRCULATION

The flushing of estuaries results from three influences: the ebb and flood of the tide, the wind stress, and the higher density of ocean water relative to river water. Some estuaries are influenced equally by the three factors, some by only one or two. Which factors are important controls how the estuary flushes its pollutants, and, perhaps more importantly, determines the effect of such projects as dredging, harbor extension, and the like. This section describes five types of circulation. The first, gravitational circulation, results from the relative heaviness of ocean water; the second, third, and fourth are three different mechanisms caused by the tide; and the fifth is circulations driven by wind.

Gravitational Circulation

Gravitational circulation is so called because it results from gravity pushing heavier ocean water landwards up the bottom of the estuary. Figure 1 is a simplified profile sketch of a purely gravitational circulation; in three dimensions the circulation is landward along the bottom of the deeper channels, upward and transversely across the cross section, and returning seaward mixed with freshwater in the surface layers. This type of circulation has received a great deal of analytical, laboratory, and field study; Fischer (1976) discusses the results of approximately 20 previous reports.

Where there is little tide, as in the Gulf of Mexico, there may be little mixing between the ocean and freshwater; the ocean intrudes as a wedge and the freshwater rides over the ocean water. This situation occurs frequently at the mouth of the Mississippi. Similarly, in the Alaskan fjords the freshwater

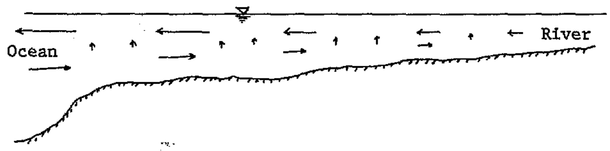

FIGURE 1.—A typical pattern of gravitational circulation in a partially stratified east coast estuary.

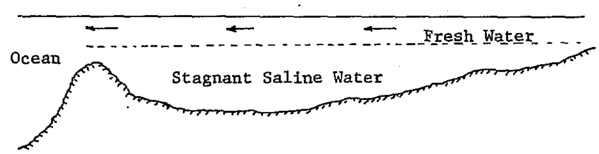

FIGURE 2.—Outflow of a layer of fresh river water over stagnant saline water; this flow pattern is typical of fjords.

overrides the salt and reaches the ocean almost without dilution (see Figure 2). In these cases the dispersal of a pollutant depends crucially on whether it goes into the upper, freshwater, or the lower, saline water. In fjords, the flushing time of the salt water may be on the order of years, while the fresh layer may traverse the fjord in a few days or at most weeks. It is particularly important that design procedures be used to make sure that pollutants are not trapped in the slowly circulating lower level.

Conversely, along the east coast most estuaries are either partially or well mixed; the difference in salinity between upper and lower layers in Chesapeake Bay, for instance, is usually on order of 15 percent of the difference between ocean and fresh water. In these estuaries it does not matter so much where the waste is discharged as turbulent mixing will distribute the waste over the cross section.

Tidal Pumping

"Pumping" is a term used to describe circulations induced by the ebb and flood of the tide. The tide usually flows in more strongly in some channels and out more strongly in others as though a pump were pushing the water around. Sometimes sailors of small boats know more about these currents than do engineers, but they are very important in flushing pollutants. Pumped currents can be simulated by numerical programs; for instance Figure 3, taken from a report by the California Department of Water Resources (Nelson and Lerseth, 1972), shows a computed pumped circulation in San Francisco Bay. Note, for instance, the circulatory current in San Pablo Bay (between Vallejo and San Rafael) having a predicted magnitude of approximately 10,000 cfs. This is about five times the combined inflow of the Sacramento and San Joaquin Rivers.

Chopping

"Chopping" is a term sometimes used to describe the detention of a pollutant by side embayments, shoals, and the like. This mechanism is also very important in the spread of pollutants, because of the typical sequence of events shown in Figure 4. In 4a a cloud of pollutant is being carried landward by a flooding tide. In 4b part of the cloud is detained in a side embayment, which is being filled by the flood. In 4c the water surface has begun to drop and the embayment is emptying back into the channel. Because of the hydrodynamics of tidal flows the current in the channel does not slack until after high or low tide, with the result that shoreline irregularities spread out a cloud of pollutant somewhat as shown in the figure.

The Shear Effect

The shear effect is an additional spreading mechanism which takes place in any flow, tidal or not. It results from the faster flow velocities found at the center and surface of the cross section, as compared to the slower velocities near the bottom and shores. Turbulent mixing spreads a pollutant across the cross section, and then the difference in longitudinal velocities spreads the pollutant up and down the channel. In rivers this mechanism is primarily responsible for longitudinal dispersion, but in estuaries the other mechanisms usually seem to be more important.

Wind-driven Circulation

The visible effects of wind are white caps and violent turbulence where waves break near shore. Impressive as they may be, they usually have little to do with pollutant dispersal, being limited in scale and unable to accomplish long distance transport. Wind does play an important role in some estuaries, however, because it can drive large scale horizontal circulation. In a large open bay a constant wind will push water in the wind direction across shallows and at the surface, while a return flow will be found underneath in the deeper section. Figure 5 shows such a circulation around an island in a bay which is deeper on one side of the island than on the other; the circulation goes with the wind on the shallow side, and against it on the deeper side. This sort of circulation has the same effect as tidal pumping; it is as though a large pump is pushing the water around and dispersing the pollutant.

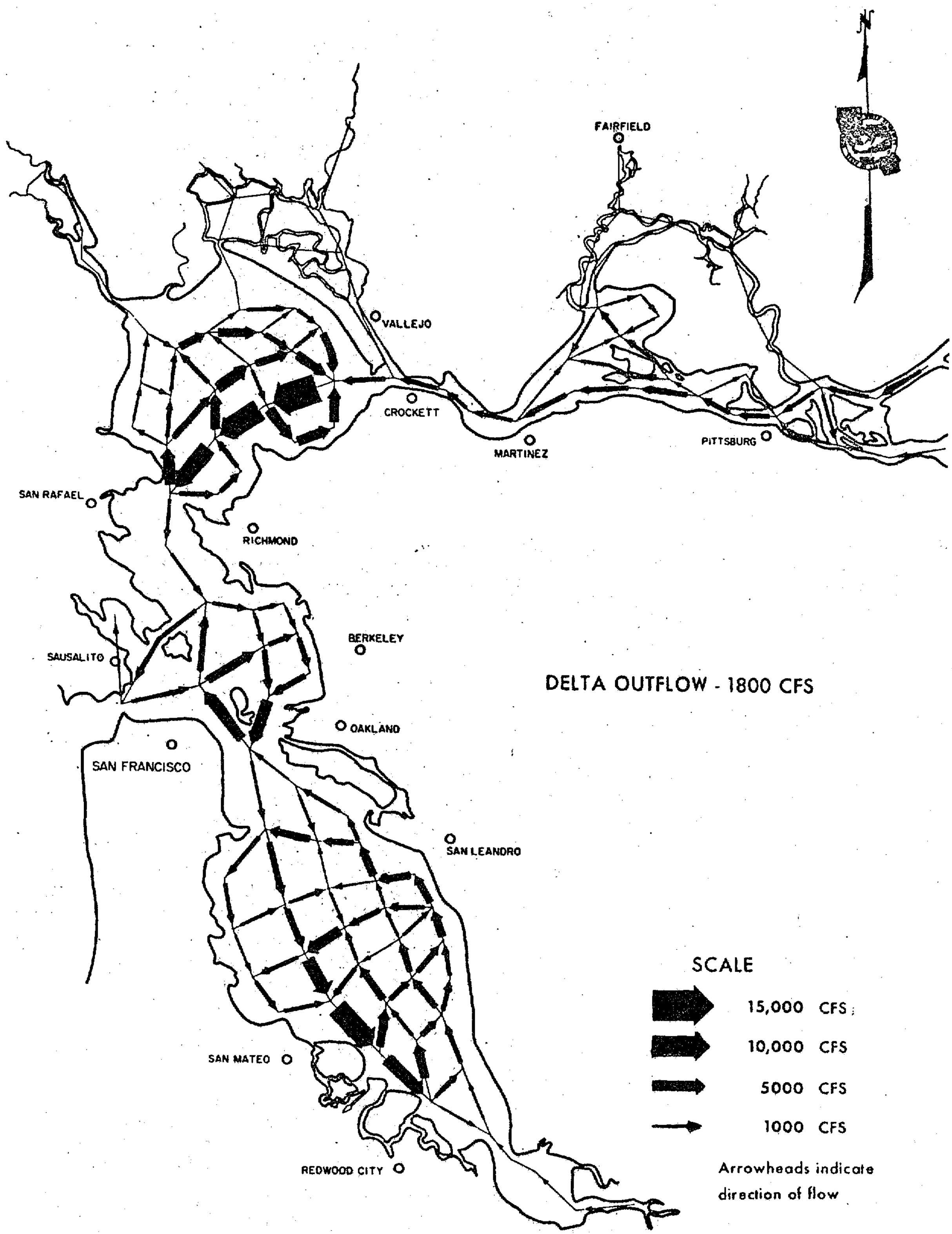

FIGURE 3.—Circulation due to tidal "pumping" in San Francisco Bay. This circulation pattern was obtained by a computer program, and is taken from a report by Nelson and Lerseth to the California Water Resources Control Board.

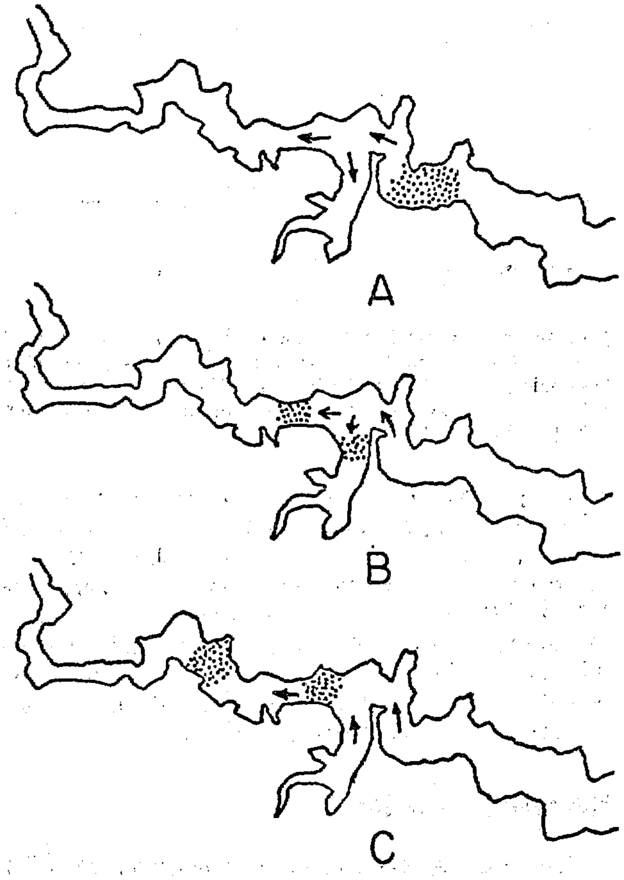

FIGURE 4.—An example of the "chopping" mechanism for dispersing a pollutant. The side embayment acts as a storing basin which fills and empties out of phase with the flow in the main channel. A portion of the cloud of pollutant is detained by the embayment and subsequently reinserted into the channel some distance from the rest of the cloud.

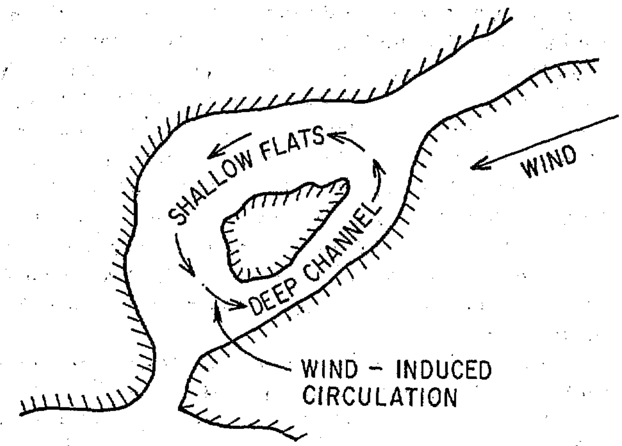

FIGURE 5.—An example of a circulation driven by a steady wind. The effect is similar to that of tidal "pumping," although the cause is different.

Each of the mechanisms described above exists to some extent in almost every estuary. In concert, the circulations result in a "flushing discharge" which can be used to compute pollutant concentrations. Each mechanism can be analyzed, but with varying degrees of accuracy and by different means. In section IV we discuss several analytical techniques and mention which is suitable for analyzing which mechanism.

EFFECTS OF CIRCULATION ON DISPERSAL

The combined effect of the various circulations is to greatly increase the assimilative capacity of an estuary by providing an effective flow much greater than the flow of the rivers which feed the estuary. This effective flow is the flow relevant to pollutant concentration computations, and is the flow that should be used for regulatory purposes. In the saline portions of existent estuaries one can compute the effective flushing discharge by a simple procedure. All one does is to measure the average salinity near an outfall; then, to a good approximation, the effective discharge is computed by the formula

$$Q_d = Q_f \left[\frac{S_0}{S_0 - S}\right] \tag{1}$$

where S_0 is the ocean salinity, S the salinity near the outfall, and Q_f is the inflow from upstream rivers. The concentration of a pollutant discharged in the vicinity of the outfall, is given by a mass-balance computation using the effective discharge.

$$C = C_0[Q/Q_d] \tag{2}$$

C_0 and Q are the concentration and flow from the outfall, and Q_d is the result obtained from equation (1) at the location of the outfall.

Concentrations upstream and downstream of the discharge point decrease from the peak near the discharge. A complete description of the analysis, for a non-conservative pollutant, was given more than 20 years ago by Stommel (1953). One important result is that moving an outfall nearer to the ocean does not decrease the concentrations of conservative pollutants in the estuary seaward of the outfall; it does, however, decrease the peak concentration and the concentrations landward of the outfall.

Stommel's analysis does have some serious limitations. First, it can only be used with an existing salinity distribution. It is of no use at all to predict changes in concentrations because of construction projects. Second, the analysis assumes steady state; the pollutant must be discharged at a constant rate, and the inflow from upstream rivers must be constant. Neither of these conditions is often seen in practice. Third, the analysis assumes complete and instantaneous mixing of the pollutant across the cross section, and a uniform salinity across the cross section. In practice, mixing within a cross section may take considerable time; for instance, a recent dye experiment in a section of the Delaware Estuary, where the estuary is about 1 mile wide, showed that the cross sectional mixing time was approximately 10 days (see Fischer, 1974). If mixing is not complete equation 2 gives a concentration that can be much too low; higher concentrations will be found in the vicinity of the outfall.

Concentrations near outfalls, and cross-sectional mixing times, may be predicted in several ways. Immediate diffusion of an effluent from a pipe may usually be analyzed as a problem of mixing of a buoyant jet. This subject has been studied in considerable detail, as described in a recent review paper by Koh and Brooks (1975). In the zone close to the outfall where mixing is controlled by the method of discharge, it is a straightforward matter to predict the dilution within the jet. This zone is usually small, however, and there is a substantial mid-field zone in which the concentration disperses as a plume, and mixing is primarily due to the turbulence in the receiving water. Figure 6 shows a sketch of a plume diffusing in an estuary. The vertical and horizontal extents of the plume and the time required for approximately complete mixing can be predicted at least within an order of magnitude in most cases, but if more exact results are needed prototype dye dilution studies are usually required.

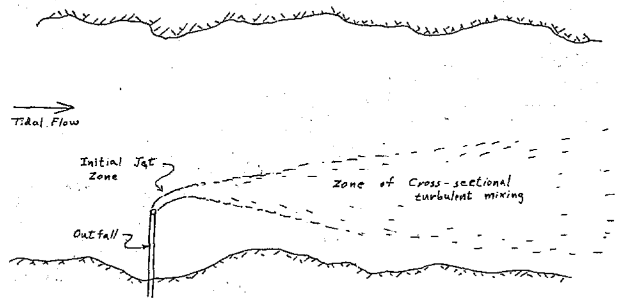

FIGURE 6.—A sketch of the zones of mixing from an outfall in an estuary. The direction of the drift changes with the changing tide, but during the tidal flow the pattern is as shown. At slack tide there is a build-up of concentration near the outfall.

STATUS OF PREDICTIVE CAPABILITY

Analytical Models

The use of analytical models is generally limited to estuaries which are long and narrow and can be considered to be one-dimensional. A basic assumption of most analytical models is complete mixing across the cross section, as in the empirical analysis described in the previous section. The use of analytical models is limited partly by their one-dimensionality, and partly by the need to assume some value of a longitudinal dispersion coefficient, whose magnitude is difficult to predict. Analytical models are sometimes useful; for instance, O'Connor (1965) gives analytical solutions for distribution of dissolved oxygen and biochemical oxygen demand in several estuaries. Recently, attempts have been made to relate the longitudinal dispersion coefficient to the salinity gradient in order to predict salinity intrusion analytically (Thatcher and Harleman, 1972, and Fisher, Ditmars, and Ippen, 1972). These efforts remain in the research stage, however, and in general it can be said that analytical models are not a dependable predictive tool unless based on empirical observations of salinity distribution.

Numerical Models

The past 10 years have seen considerable effort and progress in the development of numerical models for marine pollution. Numerical models usually consist of two parts; first, a model of the tidal hydrodynamics, and secondly, a model of the transport and reaction of pollutants carried by the tides. At the present time virtually all operative numerical models are two-dimensional. That is, the velocities and transports are considered to be only in horizontal directions along and across the estuary. The hydrodynamic portion of the model predicts the vertically averaged velocity vector at various grid points within the estuary, and then the transport portion of the model simulates the motion of pollutants which are carried by the computed velocities. Some numerical models use a fixed rectangular grid, while others use link and node arrangements or variable grid spacings so that the grid spacing can be adjusted to fit the requirements of different parts of the estuary.

Numerical models are in current use to study pollution problems in a number of estuaries. The state of the art can be shown by three recent examples. Figure 7 is from a report of a study of pollution in Boston Harbor by the firm of Hydroscience, Inc., completed in July 1973. The study used the hydrodynamic model developed by Leendertse (1967) to predict tidal velocities throughout the harbor. Pollutant distributions were computed for a number of hypothetical releases of unit waste loads; the figure shows the distribution 12 hours after a unit release at the mouth of the Neponset River. The results of the modeling study were used to predict concentrations of pollutants resulting from alternative water quality management schemes.

The second example is from a study of the dispersion capability of San Francisco Bay-Delta waters by the California Department of Water Resources. Figure 8 shows the computed distribution of pollutant discharge. The methodology of this study was somewhat different from that of Boston Harbor because of the much greater size of the bay. The north bay was modeled by a series of one-dimensional segments, and the south bay by a two-dimensional arrangement of segments. The scheme was probably not as accurate as the Boston Harbor scheme, but the scheme used for Boston Harbor requires much more computer storage and running time and to date has not been used in an estuary approaching the size of San Francisco Bay.

The third example is from a study of the dispersion of wastes from a proposed industrial outfall in the Delaware River. Figure 9 taken from a paper by Fischer (1974), shows predicted and observed distributions of dye in the river 10 days after the beginning of a continuous release. In this case most of the spreading was due to transverse mixing and the shear effect; the numerical model used, as described in the report, was specifically designed to model these effects.

Since numerical models are being used so widely, it is important to recognize that they will have limitations. The models seem to do a good job of computing the effects of tidal pumping and chopping. Wind-driven circulations can be predicted, although our knowledge of the wind stress coefficient is limited. Most numerical models do not model the shear effect very well, partly because the true magnitude of the transverse mixing coefficient is not well known, and partly because the numerical processes tend to obscure the rate of diffusion in the model. The greatest limitation of numerical models, however, is their inability to account for stratification or gravitational circulation. At the present time, numerical models of the effects of stratification are strongly empirical. In some cases two-dimensional models which consider only a vertical plane have been used, with some success, but in many estuaries, gravitational circulation and stratification have important three-dimensional components and no model is adequate. Finally, it should be stressed that the transport portion of most

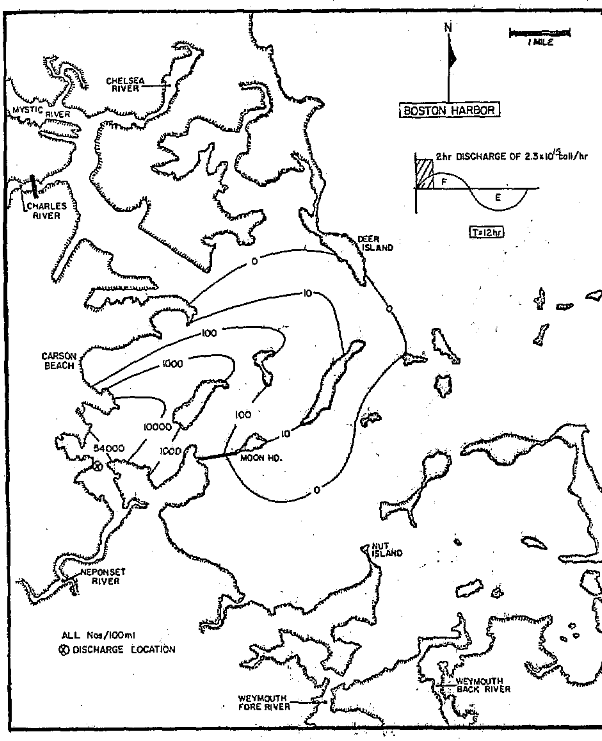

FIGURE 7.—A predicted distribution of pollutant concentration in Boston Harbor resulting from a two-hour discharge at the mouth of the Neponset River. This figure is from a report of a study by Hydroscience, Inc., to the Massachusetts Water Resources Commission.

numerical models has received very little field verification. For instance, the distribution shown in Figure 7 has not been verified in the bay itself. Even the hydrodynamic models lack extensive field verification, and their results must be viewed with caution.

Hydraulic Models

Hydraulic models have been in use for many years to study such problems as sediment transport, velocity distributions, and the effects of projects such as construction of barriers and harbors. Recently, hydraulic models have also been used for pollution studies. For instance, the San Francisco Bay-Delta model is being used to study the effects of the peripheral canal and a proposed ship canal on intrusion of salinity into the Delta. Hydraulic models have also been used to study the distribution of an effluent from an outfall, by arranging an injection of a tracer into the physical model. Where a model has already been built for other purposes, use for a pollution study is relatively inexpensive.

Hydraulic models, like numerical models, are capable of representing the effects of tidal pumping

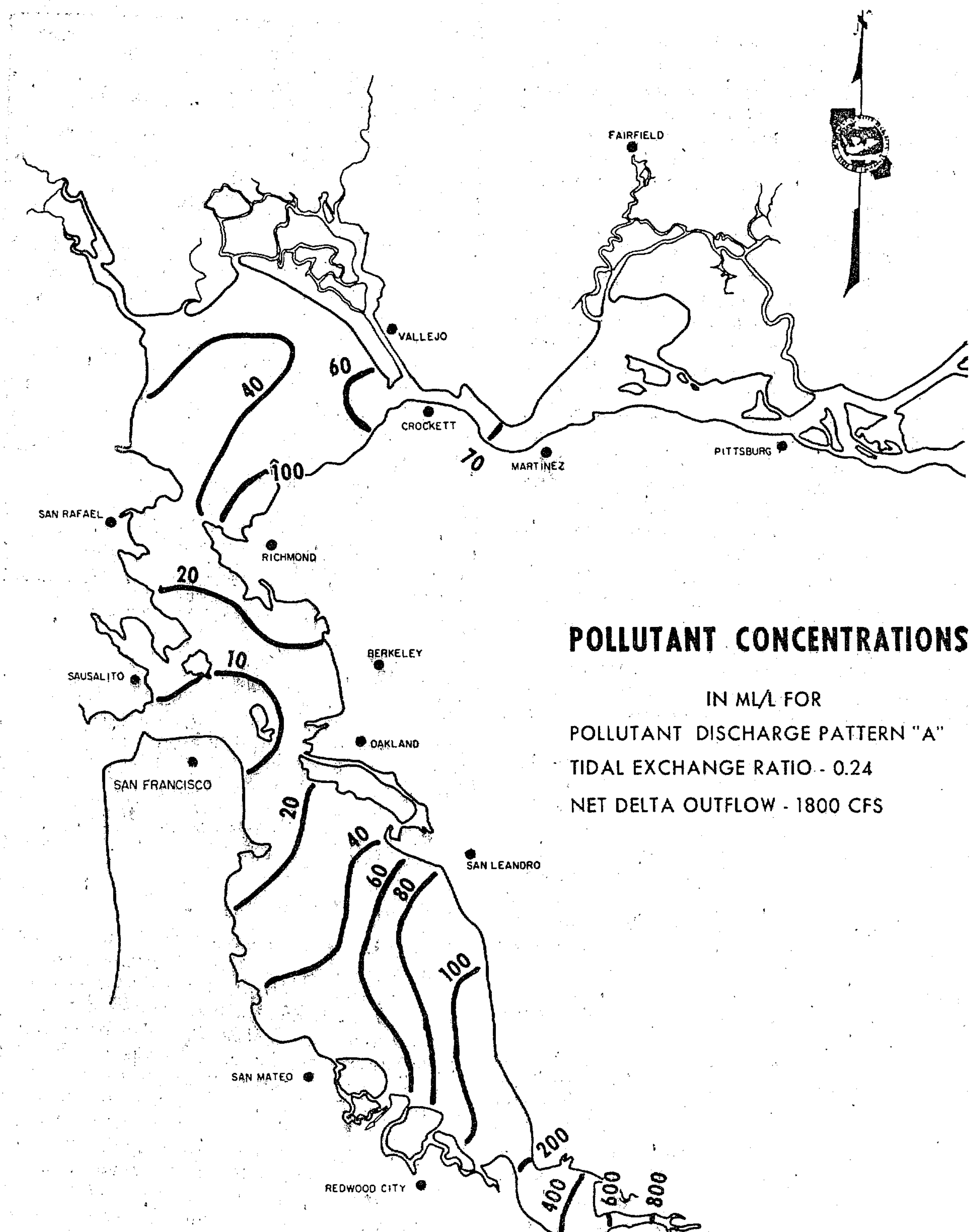

FIGURE 8.—A predicted distribution of pollutant concentration in San Francisco Bay resulting from a stipulated set of inputs, taken from a report by Nelson and Lerseth to the California Water Resources Control Board.

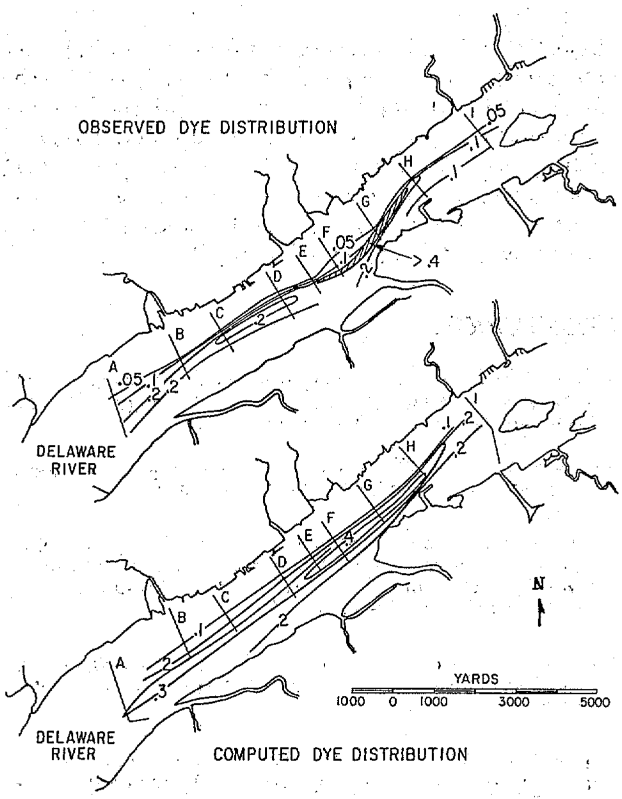

FIGURE 9.—Computed and observed distributions of dye released from the site of a proposed industrial outfall in the Delaware estuary. The dye simulates the spreading of the proposed waste discharge, and the dye results can be used to compute expected concentrations of pollutants.

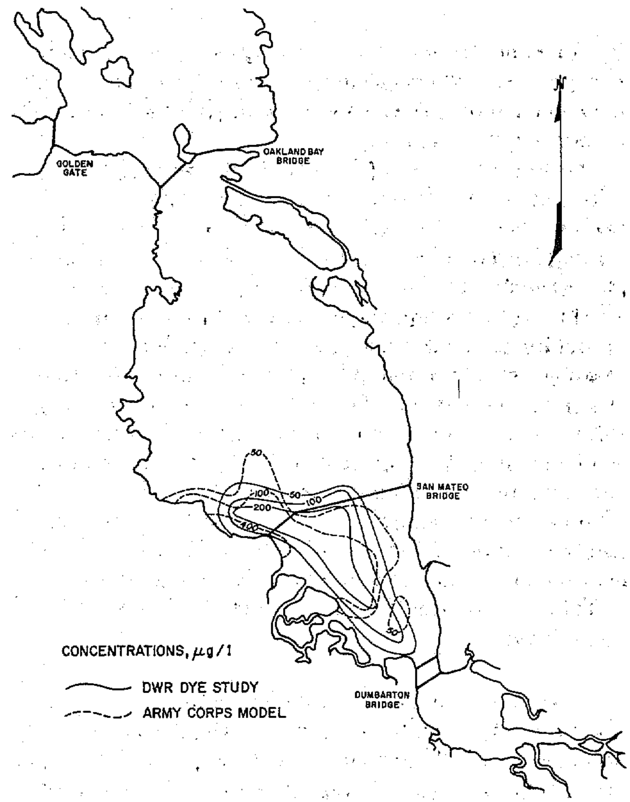

FIGURE 10.—A comparison of the spread of dye in a physical model of San Francisco Bay and in the bay itself. The dye was released north of the San Mateo Bridge near the west shore. The dashed lines are concentrations observed in the U.S. Army Corps of Engineers model; the solid lines are concentrations observed by the State of California Division of Water Resources in the bay (corrected for dye loss). Both distributions are five tidal cycles after beginning of release of the dye.

and chopping, because they are adjusted to produce the proper currents. Hydraulic models also represent the effects of stratification, although perhaps not exactly. Where three-dimensional circulations and stratification are important a hydraulic model is probably as accurate a tool as any for predicting effects of circulation, even though there is dispute over the accuracy of the results. Figure 10 shows one comparison of dispersion of dye in an estuary vs. dispersion of a similar release in a model. Unfortunately, not many such comparisons exist because of the very large amount of dye required in the prototype and the difficulty of making field measurements.

Hydraulic models do have one serious limitation. In order to conserve space and maintain turbulent flow it is necessary that the model be distorted, so that the depth is relatively much greater than the width. This means that near source distributions are distorted, and that the turbulent mixing processes are not properly represented. Thus, hydraulic models sometimes will not properly represent the near field or medium field concentrations from an outfall, even though the far-field distribution may be reasonably correct. Hydraulic models are perhaps best used in a qualitative sense; various different arrangements of outfall locations or various different designs for construction projects can be tried in the model, and the results compared. Even though the results may not be quantitatively exact, comparative results will usually determine which design will produce the least degree of pollution.

SUMMARY AND RECOMMENDATIONS

Estuaries can assimilate more waste with less effect on the environment than can the rivers which feed them, because of the flushing current from the ocean. There is a simple procedure for estimating the flushing current, based on measurement of salinity in the estuary. In many cases this procedure can be used with reasonable accuracy to predict the concentrations of wastes resulting from an industrial or municipal discharge.

In several types of cases this simple procedure does not work: in estuaries of nearly constant salinity or very wide estuaries and bays; in fjords or strongly stratified estuaries; or where the shape of the estuary is to be changed by major construction. In these cases some form of hydraulic or numerical modeling is needed to predict the effects of waste discharges. Modeling, however, requires an understanding of the type of circulation to be expected in the estuary and an understanding of the limitations of the types of models available. Modeling is not an art for the semi-skilled; there is no one model suitable for use in all estuaries, and at present a relatively small number of individuals have the training and experience required to do useful modeling studies.

These considerations lead to the following recommendations:

1. It should be understood that modeling is an art for extremely qualified experts and that sophisticated numerical models are not a necessary part of every water quality plan. Models should be used only where they are really needed, and then only by persons with extensive familiarity with the model and its limitations. Use of the wrong model can be worse than use of no model at all.

2. There should be a national listing and classification of estuaries to determine in which portions of which estuaries the simple procedure for estimating flushing currents is suitable, and in which it is not. Such a listing would be of great use to EPA in setting standards and proposing rules, as the Agency could then specify the use of the simple method where allowed by the listing, and require other methods where the simple method is not allowed.

3. Continued research, development, and training in the use of models is essential. This research should include more complete verification of the accuracy of present models, further development of numerical models, and further investigations of the limitations of numerical and hydraulic models. As part of the research there should be a vigorous program of specific field testing of present and proposed models. This research will have the benefits of producing more generally applicable and dependable models plus the desirable byproduct of increasing the pool of persons qualified to use the models.

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THE CRUCIAL ROLE OF SYSTEMATICS IN ASSESSING POLLUTION EFFECTS ON THE BIOLOGICAL UTILIZATION OF ESTUARIES

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ABSTRACT

The data of systematics form the essential foundation for pollutional biology. Living targets of pollution must be identified precisely; imprecision nullifies results and renders them nonreplicable. Most estuarine and coastal marine plant and animal groups are poorly known systematically. Major bottlenecks in the application of systematics to the problems of environmental pollution result from the critical shortage of experienced systematic specialists and technicians, as well as lack of inventories of specialists, identification publications, and identification services. Although water quality legislation implies the need for identification of organisms involved in analyses of the biological impacts of pollutants, there has been no conspicuous financial support for systematic work. Because basic and applied environmental research and its application to the practical problems of pollution have grown far more rapidly than the supporting base of systematic biology, it is imperative that existing human and material systematic resources be conserved, and their further development be encouraged. Specific recommendations are offered to maximize the service role of biological systematics in the identification and assessment of the effects of pollution on the biological utilization of estuaries and coastal waters in the United States.

INTRODUCTION

In the course of perhaps four billion years the surface of the earth has become populated by an estimated 10 million kinds of recent organisms, ordered in self-sustaining, self-regulating, ecological systems. About one million species of animals and a half million species of plants have been described, and an estimated additional half billion species are extinct in fossil strata (Mayr, 1969). Evolution tends to sustain these living systems, accumulating complex arrays of organisms that stabilize the environment, and conserve and reuse resources to support the maximum amount of life; whereas disturbance causes a systematic alteration of biotic structure (Woodwell, 1969, 1974). Estuaries, biologically complex, delicately balanced, coastal transitional zones where seawater is measurably diluted by land drainage are integral parts of the biosphere. If not perturbed, they likewise tend to be stable, self-sustaining, self-regulating, biologically productive systems (Carriker, 1967).

But human tenants on the shores of estuarine ecotones, through heedless technological activities and massive discharge of deleterious residues, continue severely to disturb these coastal zones (Ketchum, 1972). The consequences are eradication of habitats; reduction, alteration, and extinction of species; and impairment or destruction of the qualities fundamental to the health of the biosphere and the welfare of humans. The critical role of a wide diversity of organisms in promoting the health of the estuary is indisputably clear. We reaffirm with Woodwell (1974) that humanity lives as one species within a biosphere whose essential qualities are determined by other species and that we must give careful thought to these relationships. There is urgent need, accordingly, to examine in some depth the functions of systematics in the identification and assessment of the effects of pollution on the biological utilization of estuaries. This will be done in this paper.

What is Systematics?

Systematics may be defined as the scientific study of the kinds and diversity of organisms and of the relationships among them (Simpson, 1961). Although the term taxonomy is often used for the theory and practice of identifying and classifying organisms, systematics and taxonomy are often loosely treated as synonymous (Davis and Heywood, 1965); this will be the practice in this paper.

Systematic biology provides scientific names for organisms, describes them, preserves collections of them, provides classifications for them, keys for their identification, and data on their distributions; it investigates their evolutionary histories, and considers their environmental adaptations (Michener, 1970). Systematists now study organisms in all stages of their life cycles, disclosing unexpected structural details by the use of scanning electron microscopy, analyzing behavioral patterns and chromosomal configurations, and comparing the sequences of amino acids in protein and nucleic acid molecules.

Systematic biology is perhaps the oldest of the sciences, and is closely allied and complementary to ecology. Systematics is one of the fundamental perspectives in biology, integrating such disciplines as ecology and behavior with functional morphology, comparative physiology, biochemistry, genetics, and evolution.

Why Identification?

The data of systematics form the essential foundation of all other biological disciplines, especially of such interactive sciences as marine biology, biological oceanography, estuarine ecology, and pollutional biology. Wilson (1971) rightly points out that most of the central problems of ecology can be solved only by reference to details of organic diversity, and that even the most cursory ecosystemic analyses have to be based on a sound systematic treatment of the organisms considered. Pollutional ecology is no exception.

The basic functional unit in biology is the organism. Similar organisms are grouped by systematists in a species and given a scientific name, a symbol for the recognition of the taxon. Historically, precise and complete identification of organisms has not been available for many species, and has commonly been inaccurate for others. It is crucially important that the biologist know the precise identity of the organisms he studies—even more so now in view of the growing universal emphasis on estuarine and coastal marine environmental work.

The identity of microbes, plants, and animals is as significant to the microbiologist, botanist, and zoologist, respectively, as proper identification of elements, molecules, and compounds is to the chemist. Or stated in another way, the systematics of the whole organism is no less significant than that of the molecules of which it is made (Hedgpeth, 1961). Higgins (1974) notes that we have to learn to identify the living targets of pollution with the same analytical competence as the chemist identifies the elements, and to identify community structure in the same way the analytical chemist deals with his compounds. The increasing refinement and quantification of biological investigation requires comparable exactness in the identification of organisms used in both basic and applied research. Imprecision in identification neutralizes research rigor! If identifications are in error, published work becomes nonreplicable, and thus unscientific. In view of this significance, we examine next the utilitarian aspects of systematics in estuarine and coastal marine work.

Biological Censuses and Environmental Assessment

Because differences in species reflect differences in structure, function, and requirement of organisms, the first step in any biological study should be identification of the organisms under investigation (Allen, 1974; Carriker, 1967; Steere, 1971). Hedgpeth (1957) cogently summarized the argument with reference to ecology: "... an ecological investigation is essentially a study of organisms *in situ* ... The primary data of any ecological investigation, therefore, are the species of organisms concerned ... The first procedure in an ecological investigation is, or should be, essentially an exercise in systematics, the identification of species, and understanding, *inter alia*, the relation of these species to other groups in both the evolutionary and physiological senses." The significance of specific names to ecologists may be illustrated by this excerpt from a letter received by Schmitt (1953): "I have all of my voluminous field notes ready and only await the names of the specimens which I sent you a long time ago. Have you had a chance to go over them? I have the names of most, but there are still many left and I can publish nothing until I get them." Elton (1927) concludes that one of the biggest tasks confronting anyone engaged in ecological surveys, owing to the lag of the systematic study of some of them, is that of getting all groups identified to the species. A popular method of studying phytoplankton in the sea, which has purportedly obviated the need for specific identifications, employs continuous plankton recorders and chlorophyll extraction. Recent research in mariculture, however, has demonstrated the nutritional role of some species of phytoplankton, and the nuisance value of others (Epifanio and Mootz, 1974), evidence that number of individuals and identification of chlorophyll are insufficient to identify the value of species.

The magnitude of the task of conducting sound biological censuses in order to obtain a reasonable picture of biological conditions even in a limited geographic area is difficult to comprehend in terms of people, time, and money. Nonetheless, in this decade "before and after" surveys have become routine operations at sites of power plants and other technological enterprises. Various commercial groups have sprung up about the country to conduct the work. Unfortunately, some of this work tends to be superficial and lacks taxonomic credibility. To illustrate the magnitude of the job of conducting thorough, systematically sound, biological censuses, I will summarize three. These range in emphasis from basic to applied.

Open ocean.—The first was a fundamental study of the biota on a course some 5,880 miles long west of Mexico, Ecuador, and Costa Rica, and in the Caribbean (Schmitt, 1939, 1953). In 24 days at sea, Schmitt and associates collected some 11,000 biological specimens at 14 stations. Preliminary sorting was done as birds and fishes were frozen and invertebrates and plants were chemically preserved. Further sorting by two experienced biologists at the Smithsonian Institution, so that the material could be distributed to specialists for identification and classification, required about two weeks. Shipping to out-of-town taxonomists, and their acceptance and reporting extended over 35 months. Specimens went to nine different divisions in the Smithsonian and to 21 specialists in four foreign countries and the United States. Three years after distribution of specimens began, most of the reports from specialists were in hand, and by the end of another year most of the reports were in print. In summary, 26 active taxonomists were involved over a 3-year period; the 19 systematic papers published as of 1953 covered a collection of 191 families, 330 genera, and 469 species of animals, and 41 families, 70 genera, and 87 species of plants!

Cape Cod Bay.—The second is a quantitative biotic census undertaken in 1964 in Cape Cod Bay, Mass., by the Systematics-Ecology Program, Marine Biological Laboratory (Young et al., 1971). The aim of the census was to provide a synthesis of information on the kinds, abundance, distribution, and diversity of benthic estuarine invertebrates retained on a 1 mm mesh screen, in relation to particle size and organic content of the sediments, depth, temperature, and salinity in an as yet relatively undisturbed embayment. The bay was divided into 300 one-mile square grids, and alternate quadrats, about 100 of them, were sampled with four different types of gear. Samples were washed and preserved on board the research vessel, and hand sorted and identified at least to the family level in the laboratory prior to being distributed to systematic specialists. A total of 47 taxonomists collaborated in the identifications. The field work consumed some five years, and six more years were required for final sorting, distribution of specimens to specialists, return of the reports, computer analyses, and preparation of final reports. The local work at the laboratory involved eight different senior people and approximately 40 to 50 full and part-time sorters at different times over the 11-year period of the project. In all, a total of 237 families, 485 genera, and 782 species has been identified (Michael, 1975; O'Connor, 1975).

Connecticut River.—The third census is a pre- and post-operative long-term study at the site of the Connecticut Yankee Atomic Power Company nuclear generating station at Haddam Neck in the tidal region of the Connecticut River. The survey was designed to examine possible changes in the physical, chemical, and biological features along a 5-mile stretch of the river in the vicinity of the plant after appearance of the warm water plume. The study was begun in 1965 and will be completed this year (1975), 10 years later. When the plant began commercial operation in 1968, it was one of the largest nuclear plants in the world. A staff of 10 to 12, based at the Essex Marine Laboratory, on the Connecticut River, conducted the study (Merriman, 1973, 1974). In the course of the study, some 20 systematists assisted with identifications. A total of approximately 6,500 biological samples were collected, including about 150 species of bacteria, plants, invertebrates, and finfish. The final report, to be published as a single volume, will contain approximately 200 printed pages.

The question may arise as to whether such long-term, time-consuming, expensive censuses are necessary. Regrettably, obvious substitutes to this approach are not currently available; no better barometers of the biological impact of perturbations exist than organisms themselves, and there is yet no other way to obtain baseline information prior to the impact of perturbations. Identified organisms and general information about them (that is, systematics collections) still constitute the fundamental resource for basic evidence and assessment of what has occurred, what is occurring, and what can be expected to occur in the environment (Allen, 1974).

STORAGE AND RETRIEVAL

Accurate identification is the key which unlocks the storage and retrieval system of scientific information. All knowledge published on organisms is catalogued and stored in the world scientific literature under the scientific name of the species, or where the systematics is incompletely known, under the names of higher taxa in the classification. If nothing has been reported on a newly described and named species, its identification permits accumulation of information for future use. Accurate retrieval of information, consequently, can only be as reliable as precision of identification and classification. Names make information accessible on such aspects of organismic biology as geographic distribution, ecological relationships, life cycles, behavior, comparative physiology, host-parasite relationships, predators, disease organisms, biological and chemical controls, and response and tolerance to adverse environmental changes.

PREDICTIVE ATTRIBUTES

Michener (1970) indicates that placement of a species which has been inadequately studied in a genus and family makes possible prediction of some of its biological attributes. Although this may be a helpful practice under some circumstances, there are so many exceptions that it is not recommended for the non-specialist. There is serious danger that unfamiliar with species, he may apply the rule of thumb and draw false conclusions (Burbanck, 1975). Allen (1974) notes that in current extensive testing programs for determining tolerance levels of species exposed to pollutants, species that are similar in appearance do not always respond similarly physiologically. Such considerations underscore the importance of precise identification at all levels of biological work.

ELIMINATION OF DUPLICATION

Needless duplication of biological research—which is becoming increasingly costly and time consuming—can be avoided by a careful check of the world scientific literature. It is not uncommon for research to be repeated unnecessarily because the investigator did not consult the literature with sufficient thoroughness, or because identification of his organism(s) was in error. Libraries, unfortunately, store too many examples of the results of very expensive research which have been discredited because of faulty identification of species (Allen, 1974; Clausen, 1942; Sabrosky, 1955). Stunkard (in Schmitt, 1953) succinctly summarized the problem: "Much of the fumbling and stumbling in biological work can be traced directly to the failure of the investigator to recognize the organisms with which he worked." As a safeguard against repetition of error, it has become increasingly necessary that an identified sampling of species (voucher specimens) mentioned in publications be deposited in permanent accessible museums or herbaria so that scientists can check the accuracy of identifications in the literature, and consequently the reliability of the publication (Allen, 1974).

YARDSTICKS

Through accurate scientific names and preserved biological specimens, species collected at different times can serve as a yardstick for determining changes which may have, or will, take place. Thus, over a long period of time, systematics collections can play a part in revealing the rate at which evolutionary changes occur. For baseline information IDOE (1972) recommends storage of uncontaminated representative samples of plankton, fish, marine plants, and so on, in a museum specially designed for preservation of environmental voucher specimens (organisms, water, sediment, and air particles) where subsequently they may be used as indicators of normal levels of pollutants.

Some species of living organisms, more sensitive to environmental deteriorational stress than others, provide warning signals of pollution by physiological or behavioral responses; while other species, less affected by environmental change, respond to the changes by unusual increases in abundance (Olson and Burgess, 1967). Shuster (1974) suggests that by identifying the species most sensitive to pollution, workers might recognize the impacts of pollution long before it affects common, generally less sensitive, species. Thus recognition of a "sick" ecosystem might not require a species-by-species accounting. The stickler here is the problem of recognition of species sensitive to specific pollutants, to what degree such species could serve as accurate barometers for the health of an entire ecosystem, and whether they have been insensitized to the pollutant through prior exposure. Rare species, possibly because they may live closer to the limits of critical environmental factors than common species, may make more sensitive indicators than common species. Burbanck (1975) suggests that we place more emphasis on noncommercial organisms as indicators. Since they have no economic value and are thus less disturbed by human collecting devices, they might constitute more sensitive indicators than species periodically buffeted by collectors. He also believes that true estuarine species might be more sensitive than marine species which move in and out of estuaries.

BIOLOGICAL CONTROLS

Accurate identification will also become critical as the use of pesticides is replaced by specific control organisms. These species are often difficult to distinguish from closely related and nearly identical forms that feed on different hosts. To date little has been done to control estuarine and coastal marine pests by other organisms.

INDUSTRY, FISHERIES, AND CONSERVATION

The following striking examples were cited by Schmitt (1953, 1954) of the value, often with substantial monetary return, of identification in these fields.

1) Marine bivalves penetrated the outer casing of a power cable lying on the bottom of the bay between Palm Beach and West Palm Beach, Fla., in the 1940's, causing a series of serious blowouts. Adult burrowing bivalves were identified as a new species incapable of escaping from their burrows. The problem was easily solved by burying the cable beneath the bottom of the bay where the molluscs suffocated.

2) A specialist on the systematics of benthic sipunculid worms was asked in 1953 for copies of his technical publications by an Alaskan cod fisherman who had found that where these worms occur he made good hauls of fish. The fisherman wanted to plot the distribution of the worms in order to enhance his fishery and extend his operation.

3) In 1954 a sport fisherman took a specimen of a mantis shrimp to a national museum. He sought information on its mode of life, distribution, and abundance. A systematist, after identifying the specimen, learned from the literature that the stomatopod is the favorite food of certain panfish taken by fishermen in the Chesapeake Bay—and thus the sport fisherman's interest in the species.

4) In the Carolinas shad enjoy legal protection. In order to catch violators and enforce the conservation laws, state conservation agents must be able to distinguish between four or five species of fish, all superficially more or less alike.

HOW DOES SYSTEMATICS AID IN IDENTIFICATION AND CONTROL OF POLLUTION?

Pollutional biology is a subdivision of ecology, and serious ecologists recognize that their work must be based on sound specific identification of the organisms they are interpreting (Humes, 1974). Patrick (1949) was one of the first to stress this in the evaluation of the kind and duration of stream pollution. Her research demonstrated that there is no satisfactory shortcut which avoids identification of species involved. Tarzwell (1974) in the course of some 40 years of investigating pollutional zones of streams in various parts of the country, discovered that what may be considered sensitive or resistant species in one stream may not necessarily be so in another stream; in a different region these sensitive or resistant species may be replaced by closely related species. He also found that characterization of population changes in streams over time as waste is introduced can be made only by specific identification of organisms. Pawson (1974), furthermore, stressed that to understand interactions between organisms and pollutants, one must be quite sure that the organism in question represents one species, and not a group of several species.

Systematic studies are also essential in establishing the quantitative characteristics of estuarine communities before real or possible pollution occurs; otherwise, effects of pollution may not be detectable (M. Abbott, 1974). Tarzwell (1974) noted that it is both the qualitative and quantitative composition of the biota of streams which indicate the severity of pollution and the distribution of pollutional zones. To control pollution, therefore, we must know the organisms affected and be able to recognize introduction and extinction of species (Turner, 1974). The need and value of accurate identification in pollutional biology are also emphasized by Pimentel (1971) in a publication for the Office of Science and Technology on the ecological effects of pesticides on nontarget species, and by Battelle (1971) in a report for the United States Environmental Protection Agency on the effects of chemicals on aquatic life. Unfortunately, misclassification of *Balanus* sp. under the phylum Mollusca in the latter work tarnished the credibility of the systematic emphasis.

Some workers recommend the use of diversity indexes for detection of the effects of pollution on the community as a whole. A species diversity index, however, being only a single parameter of a complex system, has merit only if cautiously interpreted (Hedgpeth, 1973), and provided, as should be the practice, that species are carefully identified. This is not always the case. Some investigators identify and count microorganisms only to suborder and family, and employ these taxa for calculation of the indexes (Allen, 1974). We must emphasize that proper systematic skills and familiarity with species-differentiating traits are necessary to construct accurate indexes (Williams, 1974). In spite of the general value of indexes, however, individual species cannot be overlooked: changes in their abundance may occur which are not detectable by the index alone (Watling, 1974). To be properly used, species diversity should also include the complexities of life cycles and trophic levels (Burbanck, 1975).

There is a tendency among some workers, when dealing with groups of organisms which are difficult or not well known taxonomically, to carry identifications only to familial or genetic levels. Turner (1974) argues with reason that this is simply not enough! By taking her identifications to the specific taxon, she was able recently to recognize introducton of tropical species of the wood boring bivalves, Teredinidae, into the warm water discharge canal of a nuclear generating station in New Jersey. Had she identified the borers only to genus, she would have missed the tropical introductions altogether, and this critical aspect of the impact of the power plant on its local estuarine environment would have gone unnoticed.

Systematics can be used to considerable advantage in assessing the effects of changing environmental conditions by recognition and study of variations in the morphology of organisms. The method has been little explored and merits much more attention. Estuarine species may be more plastic than oceanic forms, and may thus reflect the effects of pollution more readily (Watling, 1974); Rasmussen's (1973) documentation of the variability of the genus *Gammarus* in his study of the Isefjord fauna is a good example of morphological plasticity. Remane and Schlieper (1971) recorded other examples.

Success in reducing or eliminating low levels of harmful pollutants, recognized only with difficulty by chemical means, is determinable biologically and with reliability by the responses of the organisms affected. Some pollutants may exert their effects in very minute amounts over long periods of time. Exposure to sublethal concentrations of detergent, copper, and zinc, for example, caused fatal anatomical abnormalities in the second generation of the polychaete *Capitella capitata* (Reish et al., 1974). Other pollutants may be progressively concentrated in food chains, and still others may interact synergistically. The latter may result in insidious alteration of aquatic environments, especially of estuaries (Odum, 1970). Yet additional organisms, preadapted to survive or thrive in certain polluted environments that are noxious to most other organisms, become indicators of that pollution (Olson and Burgess, 1967). Systematic knowledge of "normal" biotic structures provides the base for comparison with that of poisoned communities.

One of the potentially most damaging categories of change which can be brought about by man, resulting in decimation of entire species, is loss of genetic information through pollution-induced environmental change. Processes leading to extinction of large animals and plants are no longer likely to go unnoticed even if they cannot be interrupted. In certain cases predictions of immediate consequences, such as Cousteau's recognition of potential change in the oceans should filter feeding whales be eliminated, are recognized. However, dearth of information on small estuarine metazoan organisms, like nematodes, prevents any reasonable capacity for predicting the consequences of pollution to the environment in the context of these small invertebrates. Although levels of pollution are probably most effectively measured by physical and chemical techniques, impact of pollution is best measured in life systems, and thus the requirement to recognize the total dependence of pollutional ecology—no, all ecology—upon the sophistication and thoroughness of its foundation in systematics! The consequences of pollution to the earth and to man are of such magnitude that a compelling case is readily made for the study of a broad spectrum of micro-, meta-, and macroorganisms in assessing any influence of pollutants. However, such undertakings remain so primitive and inadequately supported that a major research effort, to be measured in decades, is still required to determine the full extent to which systematic knowledge, especially of small organisms, can significantly aid in the identification and control of pollution (Murphy, 1974).

What is said by Murphy about small metazoans in the identification and control of pollution, applies to an even more critical degree to such ubiquitous, abundant, estuarine microorganisms as fungi, yeasts, bacteria, viruses, and so forth. Bacteria, for example, are more important than most of us realize in pollutant transfer, biological degradation, carbon assimilation, and possibly in the control of soluble concentrations of elements (Alexander, 1973). Viruses, minute, highly mutable agents, are common in estuaries, move in the ground water, and inhabit water reuse systems, but lack of information on their behavior in these systems has impeded development of the reuse of water. Cooke (1969) is pessimistic about the emergence of general descriptions of the remarkably complex behavior of natural populations of microorganisms in native waters, and notes that research on the role of microorganisms in pollutional biology must include study of specific chemical compounds and measurement of their degradation products. I would recommend, in addition, that the research must include intensive systematic investigations (a) to provide the essential scaffolding upon which to hang the results of the pollutional research and (b) to aid in its interpretation.

Summary.—Field systematics aids in the identification of the kinds, distribution, severity, and duration of pollution at individual, populational, community, and ecosystemic levels. It does so by revealing (a) changes in the proportion of abundance of individuals, (b) alteration in the composition of species (by elimination of some and introduction of others and changes in ecological succession), (c) modifications in morphology, physiology, ecology, behavior, and development at individual and populational levels, and (d) emergence of hardy indicator species which survive or even thrive in the altered environment. Systematics also aids in identifying laboratory experimental organisms for study of the biological effects of pollutants on them, and their responses to the pollutants.

Systematics contributes to control of pollution in the sense that populations and physio-ecological systems, which themselves function in reducing or rendering innocuous the effects of pollutants, can be recognized and augmented. Such species systems are abundant, especially in the microbiological realm where they serve as shock absorbers in buffering the effects of chemical perturbations.

Beneficial Effects of Increase in Systematic Knowledge and Services

An increase in knowledge and services in systematics will accelerate the rate, and make possible expansion, of systematics-dependent environmental investigations currently in progress. It will also open to investigation problems not now undertaken because of the difficulty or impossibility of obtaining needed identifications. Questions are not now being asked on the identification and control of pollution, or go unanswered or are delayed, because of inadequacy of identification services and facilities; answers to these questions would probably materially enhance biological assessment of the impacts of pollution, and thus of pollution control (Michener, 1970). The interstitial fauna, for example, are poorly known (Hulings and Gray, 1971), yet intertidal beaches and tidal marshes in estuaries are the first zones to be attacked by floating pollutants. Comprehensive knowledge of these fauna might reveal improved ways of determining the impact of the various fractions of these pollutants. Adequate knowledge of interstitial organisms, most of which are minute and many are abundant, would make available large numbers of them for the assessments.

A decrease in knowledge and services of systematics would unquestionably mean that causes and effects of pollution would remain unknown or confused (Wigley, 1974). Pollutional researchers would find themselves in the same situation faced by many physiologists who a few years ago based researches and conclusions on improperly identified organisms (Humes, 1974). Under these circumstances possibilities for duplication of experimental work or for making comparisons of seemingly similar situations would be slender indeed, and in fact, any comparisons would be automatically invalid (Pawson, 1974). If one remains unsure of the organisms he is dealing with, results of investigations based on them will likewise be questionable and uninterpretable. In this regard, closely related species, particularly sympatric species, must be very carefully identified.

Should systematics not be supported, Turner (1974) envisions a decreasing number of systematists, and chaos when scientists report experimental results on incorrectly identified organisms. Higgins (1974) stresses that no cause and effect analyses of any ecosystem can occur without precise identification of both the biotic and abiotic components, and because of its extraordinary complexity, this applies to the estuarine ecosystem above all others. Murphy's (1974) concern, if systematics continues at its present low level of support, is that international, national, and local policy directed at pollutional control, and purportedly based on ecological considerations, will continue to be pursued with a totally inadequate data base.

WHAT HUMAN ESTUARINE ACTIVITIES REQUIRE IDENTIFICATION SERVICES?

Allowing the world ecosystem to function in a viable, healthy way is a responsibility as well as an awesome challenge to man. The responsibility can be met, in part, by maintaining a high level of biological diversity which is commensurate with biotic stability and insures against the onslaughts of climate and disease (Steere, 1971). But a pervading thrust, intrinsic in man's recreational, fishing, technological, and control activities is making the task of preserving diversity increasingly difficult. Nowhere on the globe is this thrust more stridently evident than along coasts and estuaries. Organisms, including much of the human population, find themselves unwillingly embroiled, often helpless victims, of biotic instability in increasingly ravaged environments.

Since kinds of species and numbers of individuals are ingredients of diversity, it is necessary that periodic biotic assessment of the impact of man's

Table 1.—Human estuarine activities requiring identification and classification of organisms

Activity	Organisms
Recreation	Species harmful or potentially harmful in recreational activity which takes people into the water, or in the course of which there is danger of falling into the water; example, sea nettles.
Sports and commercial fishing	Species taken commonly such as finfish, as well as species which could be taken but because of custom are not, such as squid and conchs; potentially poisonous species, as shellfish causing paralytic poisoning in man.
Artificial structures	Species influenced by, affecting, or associated with manmade bulkheading, piling, wharfs, anchors, buoys, island structures, barnacles.
Construction and operation of power plants	Species associated with, influenced by, or affecting cooling waters, thermal plumes, cooling towers, radioactive discharge, and plant conduits through which water passes; attached algae.
Exploration and development for oil and gas	Species associated with, influenced by, or affecting exploration, rigs, towers, pipe lines, etc.; spills and discharges; fouling organisms of all kinds.
Extraction of minerals	Species influenced by, affecting or neutrally associated with mining of sand, gravel, metals, and other mineral resources (less gas and oil); surf clams.
Sediments: dredging and filling	Species influenced by, affecting, or associated with sedimentation and erosion resulting from this activity; tube worms, oysters.
Placement of wastes	Species influenced by, affecting, or associated with the dumping of liquids and solids, or involved in effluent sinks; mussels.
Biological control	Species used in control as well as those affected directly or indirectly by biological control; none yet employed in coastal waters, but approach is promising.
Chemical control	All target and associated non-target species in the area of pesticide spraying; intertidal oysters and mussels.
Ecological surveys (pollutional)	Basic surveys; wherever possible all species sampled; applied surveys: as representative identification as possible (the problem: don't always know what species are representative of communities).
Impact statements	All species known, or postulated to be involved, in anticipated activity.

activities be made. A brief catalogue, suggestive of those activities in which estuarine organisms require systematic identification, is presented in Table 1.

What Organisms Should Be Identified?

Only a few non-taxonomists appreciate how poorly most plant and animal groups are known taxonomically. A striking illustration of this was presented by Remane's work on the microscopic marine fauna of the Kieler Bucht, an area previously considered to be well known. By thorough search and with the application of new methods, Remane found 300 new species, including representatives of 15 new families, in 10 years (Mayr, 1969)!

In time, with improved systematic resources and support, identification of most species should be required. Why? The answer is implicit in observations paraphrased from Woodwell (1974): If qualities of the environment that are essential for certain types of life are changed, the structure of natural systems will change. The species favored are those whose populations can respond most rapidly to the changes. These species are mostly small bodied, rapidly reproducing forms that can exploit altered conditions. Such modified conditions increase the frequency of rapidly reproducing pest and weed species. When chronic disturbance of any kind changes the structure of natural ecosystms, populations of hardy resistant organisms characteristic of impoverished sites increase, food chains are shortened, and the capacity for support of all life is reduced.

Until more adequate systematic services and financial support are available—but as a short term expedient only—precise identification in applied work could include appropriate representatives in at least the functional categories of estuarine and coastal organisms listed in Table 2. Which species of plants and animals should be emphasized would depend on the mission of each investigation. The unsolved problem in this approach is the serious difficulty of defining what constitute representative organisms!

On the surface it might seem that the systematics of estuarine species might be less complex than that of marine groups because their number is proportionately less. Potentially, however, the problem is as, or more, complex, because the estuarine systematist has to be prepared to deal with, not only marine species which normally move in and out of estuaries, but those which may extend their ranges, be introduced by storms, coastal birds, or human activities, or float down rivers and streams during stormy periods.

Why Not Ignore Undescribed Organisms?

Is it necessary in both basic and applied biological work to consider those organisms which man has not yet named and described, and which, therefore, are unavailable for consideration until taxonomically treated?

Some (Ehrlich, 1961; Raven et al., 1971; Sokal, 1970) would argue (a) that we should restrict identification and classification to those organisms which are of actual or potential value, and (b) that to insist that it is necessary to name every living organ-

Table 2.—Functional groups of estuarine and coastal organisms which should be considered for identification in the assessment of the impact of pollution.

Groups	Examples
Commercial and sports organisms: used and potentially useful	Phytoplankton, seaweeds, sponges, corals, bivalves, gastropods, cephalopods, polychetes, decapod crustaceans, fin fishes, sea turtles, porpoises, dolphins, whales (see Shapiro, 1971).
Organisms associated with commercial and sports organisms	Competitors, mutualists, commensals, predators, and food organisms (see Henry, 1966); disease and parasitic organisms: viruses, bacteria, fungi, sporozoans, ciliates, trematodes, cestodes, nematodes, copepods, isopods, gastropods (see Sindermann, 1970).
Organisms poisonous or potentially poisonous or harmful to humans as food, in swimming, or in other recreation	Animals that bite or sting: sharks, sting rays, manta, barracuda, moray eels, cat fishes, scorpion fishes, toad fishes, sea bass, sea lions, killer whales, tridacna clams, sea nettles, cone gastropods, octopuses, sea urchins (see Halstead, 1959); poisonous to eat: shellfish which have consumed toxic dinoflagellates, poisonous sharks and rays, moray eels, poisonous fin fish (see Halstead, 1959); parasites: amebas, trematodes, cestodes, nematodes; disease organisms: viruses, bacteria, fungi, yeasts (see Cheng, 1967).
Organisms fouling surfaces of estuarine structures	Algae, fungi, protozoans, sponges, coelenterates, bryozoans, annelids, bivalves, tunicates (see Woods Hole Oceanographic Institution, 1952).
Organisms over, on, and in areas to be, or being used for mining, dredging, filling, waste disposal, power plants, oil and gas exploration and development	Most lower plant, invertebrate groups: plankton, nekton, epifauna and epiflora, infauna, meiofauna.
Organisms blocking screens of power plant intakes and other marine operations	Primarily nekton: fin fish, some crustaceans; macroscopic algae.

ism in order to complete the job of systematics, ignores the necessity for judicious sampling in our efforts to understand the universe. This point of view, unfortunately, overlooks the critical question "How are actual and potential value determined?" It also dismisses the significance of biological classification which is intended to provide a framework on which to arrange all levels of all available biological information. Clearly, substantial gaps in the framework leave voids in the content within which relationships can be expressed (Heywood, 1973).

Others, whose point of view I share, feel that the primary job of exploring the flora and fauna of the earth's surface desperately needs doing because the natural resources of the globe are being destroyed at a fearful rate and hundreds of potentially invaluable species will be wiped out of existence even before they are made known to science, much less analyzed for potential utilization (Fosberg, 1972; Keck, 1959; Mayr, 1969; Steere, 1971). Many of these species may be found useful horticulturally, agronomically, and economically, as food, forage, timber, fiber, pulp, medicine, ground cover, and so on. (Keck, 1959). For example, (a) the sperm whale is nearing extinction with loss of its natural product, sperm oil, but botanists discovered that an obscure desert plant called jojoba produces a liquid wax which may function as a substitute; (b) a little-known beetle produces a medically important drug, cortisone, in amounts equivalent to the adrenal glands of 1,300 cattle; and (c) prostaglandins, important hormones available in very limited natural supply, occur in quantity in a soft gorgonian coral in the West Indies (Evans, 1973). Furthermore, we do not know whether certain organisms are essential to the continued functioning of the ecological processes on which our continued tenure on the planet depends (Fosberg, 1972)—and we dare not risk not finding out!

To complete the task of identification of all species will require the labors of several more generations. Considering the limited number of specialists, we must take it for granted that a large part of the majority of the kinds of plants and animals will remain unsampled, unnamed, and unclassified for decades to come (Mayr, 1969). At present probably one-third of the living species of fishes remains unknown. Our inventory of invertebrate animals remains seriously incomplete. Insects are far and away the most numerous in species, and the least known. Oceanic and estuarine plant and animal life is very incompletely understood. Knowledge of the species of bacteria, viruses, yeasts, and fungi is sparse, a serious deficiency considering their great economic importance and the vast number of species (Steere, 1971).

Many well-known plant and animal species have passed into extinction in the last 150 years (Steere, 1971), and thus are irreplaceable. It is postulated that literally thousands of species will become extinct in the next generation in all parts of the world as a result of the growing human population, pollution, and habitat destruction (Mayr, 1969; Terborgh, 1974; Uetz and Johnson, 1974). Raven et al. (1971), even more pessimistic about the survival of species, doubt that even 5 percent of the world's undescribed organisms can be added to our inventory before the currently undescribed 80 percent or so of the world's organisms become extinct.

Woodwell (1974) vividly summarized the trends and the consequences of extinctions:

> This is the pattern of life now, slow, progressive, cumulative and unidirectional as species are eliminated; the pattern is already widespread, perhaps worldwide in some degree. It leads, not to a clear crisis, a cataclysm, but to the slow erosion of the quality of environment; to the loss of fish in fisheries, to the accumulation of pests, plant and animal; to the gradual erosion of the

capacity of environment to stabilize water flows, to provide clean water, fiber and food, to hold and recycle nutrients on the land. It leads to accumulation of biotically impoverished zones almost without notice, zones that are progressively less capable of supporting life, including man, and it leads to a steady increase in requirements for human intervention in the basic function of environment: more dams and more pesticides.

I am convinced that all organisms on the globe have a functional role, directly or indirectly, of consequence to man. In spite of the enormity of the task, we must proceed with a sense of urgency in the systematic exploration of the world's biota in order to salvage at least the most critical species prior to their possible extinction.

HOW ADEQUATE ARE TAXONOMIC IDENTIFICATION PUBLICATIONS AND SERVICES?

The lack of inventories of systematic specialists, publications on identification, and taxonomic identification services constitue a major bottleneck in the application of systematics to the serious problems of environmental deterioration. In the United States we are fortunate, indeed, that an active, dedicated group of biologists has recently organized nationally as the Association of Systematics Collections with the primary goals of improving (a) the condition of biological systematics collections as a national resource, and (b) the quality and efficiency of systematic services associated with these resources (Irwin et al., 1973). It is regrettable that several years may elapse before these services will be available at the level of performance at which they are so badly needed.

Systematic Specialists

No current lists of systematists and their fields of specialization exist. An international directory of botanical specialists appeared in 1958 (Roon, 1958), and another on zoological taxonomists of the world was published in 1961 (Blackwelder and Blackwelder, 1961). Regrettably, these are now somewhat out-of-date. As a result one must generally rely on word of mouth for this information, a not very efficient means of distributing scientific data.

Identification Resources

Taxonomic information on a limited number of estuarine and coastal marine plants and animals is generally available and reasonably complete, but that on most others is scattered and coverage is

Table 3.—Status of taxonomic publications for identification and classification of macro- and meiofauna in the estuaries and continental shelf of the middle eastern United States. (References are not listed in the literature section of this paper).

Macrofauna

Porifera: deLaubenfels (1949), Hartman (1958), and Wells, Wells and Gray (1960) are good sources, but no comprehensive guide is available.

Coelenterata, Hydrozoa: Fraser (1944) is thorough but difficult to use, and species are often difficult to distinguish; Nutting (1900–1915) is better but doesn't cover all families; many species need redescribing.

Coelenterata, Anthozoa: no complete source.

Rhynchocoela: Coe (1943) is excellent, but some knowledge of internal morphology is required.

Annelida, Polychaeta: some groups, such as the distinctly errant families, are covered well in sources like Pettibone (1963), but there are serious difficulties with some sedentary families, for example, the Cirratulidae and Capitellidae. Day (1973) is also helpful.

Sipunculida: the recent paper by Cutler (1973) is very helpful.

Mollusca: the second edition of Abbott's (1974) book is indispensible since it lists all molluscs found off this coast and gives references to descriptions.

Crustacea, Cirripedia: the unpublished preliminary report by Zullo (1963) is helpful, but is relatively unavailable.

Crustacea, Mysidacea: Tattersall (1951) is thorough, but difficult to use; a handbook by R. Wigley is in preparation.

Crustacea, Cumacea: no complete source is available; a handbook by L. Watling is in preparation.

Crustacea, Tanaidacea: no complete source is available.

Crustacea, Isopoda: the handbook by Schultz (1969) is excellent for identification.

Crustacea, Amphipoda: Bousfield (1973) is excellent for the more commonly found species; some of the older monographs are needed occasionally.

Crustacea, Stomatopoda: Manning (1974) covers the few local species.

Crustacea, Decapoda: Williams (1965, 1974) are both excellent.

Bryozoa: papers by Osburn (1912) and Maturo (1957) are very useful; however, a comprehensive guide is much needed.

Echinodermata, Asteroidea: no complete source is available, but Gray et al. (1968) is helpful.

Echinodermata, Ophiuroidea: no complete source.

Echinodermata, Holothuroidea: Deichmann (1930) is very good.

Urochordata: the monograph by Van Name (1945) is excellent, but difficult to obtain.

Meiofauna

Protozoa: Borror (1973) covers the genera of ciliates. While there is a profuse literature on Foraminifera, no comprehensive key exists; there are no complete sources for other protozoan groups.

Platyhelminthes: no complete source.

Gastrotricha: no complete source, taxonomy is unsettled.

Kinorhyncha: American species largely unknown, and generally overlooked.

Nematoda: no complete source; many species from American Atlantic waters have been described, but the nematode fauna from mid-Atlantic shelf waters is virtually unknown.

Annelida, Archiannelida: no complete source.

Annelida, Oligochaeta: identification of species is difficult but has been made considerably easier by the papers of Brinkhurst and Jamieson (1971) and Cook and Brinkhurst (1973).

Crustacea, Ostracoda: many scattered papers, but there is no complete source.

Crustacea, Copepoda: harpacticoid copepods from the mid-Atlantic continental shelf are not well documented.

seriously incomplete and spotty. Especially lacking are taxonomic monographs on major and minor taxa; illustrated keys, manuals, check lists, and atlases; and authoritatively identified, representative, accessible collections of organisms, their photographs, and resource literature (Carriker, 1967).

Selection of some taxonomic groups for study is too often guided by chance rather than by careful choice on the basis of the greatest void in knowledge. In other groups, systematists have not had the time or assistance to prepare syntheses, even though much of the technical information may be at hand. Then there are whole phyla, especially among marine invertebrates, for which there are no authoritative specialists. Moreover, early stages in the life history of the biota are generally less well-known than adults; least known are the micro-, meio-, and small megabenthos. These several groups therefore pose insurmountable systematic barriers to most ecologists. The absence of systematic information has been circumvented by some biologists by giving potential species arbitrary codes until such time as these organisms can be investigated systematically. This expedient, however, excludes the value of positioning species in the classification scheme for interpretative analysis based on relationships.

The seriousness of the problem of inadequate identification resources is emphasized by Chace (reproduced in Schmitt, 1953, Appendix A) and Watling and Maurer (1974).

Chace in a revision of his list on the status of the systematics of recent invertebrates other than insects, included comments on 44 major taxa. The following observations are representative.:

> . . . identification difficult or impossible without living material; more specialists greatly needed; virtually impossible to obtain identifications; the only experienced taxonomist is too busy with teaching and administration for identifications; large collections still awaiting identification; few publications; the only specialist is retired; poorly known groups, need much more study; the only specialist just deceased; intensive studies now in progress; group fairly well covered, but world monograph needed; coverage reasonably good except for Atlantic species.

Clearly, prospects for identification were not promising.

The data compiled by Watling and Maurer (1974) indicate that a grave problem still faces benthic ecologists in establishing monitoring programs, and that progress in systematics has been slow since the preparation of Chace's list (Table 3).

Watling (1974) observed that most groups (the Mollusca, for example) have received systematic coverage that is usually inversely proportional to their ecological importance but directly proportional to their size, color, and ease of handling! Though some improvement is evident in the number and quality of identification publications, the level is still far from what is required and must be achieved in a reasonable time if we are to meet the needs of pollutional ecology and other fields of biology.

In some regions of the United States the serious void in identification publications is being partially filled by series of illustrated identification manuals prepared aperiodically by collaborating systematic specialists as resources and time are available.

One of these, the "Marine Flora and Fauna of the Northeastern United States," is well underway and provides a model for the organization of similar series on other coastal regions where none exists (Carriker, 1974). The first manual was published in 1973, and since then five additional ones on coastal plants and invertebrates have appeared, printed for the advisory board of the series by the National Marine Fisheries Service in NOAA Technical Reports. Some 80 systematic specialists in the United States and a few abroad are contributing manuscripts. Much of the work on the "Marine Flora and Fauna" is done as a "labor of love," support, if any, coming from whatever source is available.

A second series, "Manuals on Marine Organisms," dealing with tropical Atlantic American fauna, being prepared by G. L. Voss and F. M. Bayer and associates, University of Miami, is representative of biota of the southeastern United States. Two guides, written for use by non-specialists in the fisheries and environmental fields, have been published, and several more are in preparation. Basic information on poorly known groups is published in another series, "Fauna Caribaea."

A third series, "Biota of Freshwater Ecosystems," sponsored by the Environmental Protection Agency with the assistance of the Smithsonian Institution, is a valuable series of identification manuals on North American organisms prepared by specialists (Smithsonian Institution, 1972–1973). Although not directly applicable to coastal waters, the set is an important supplement in the identification of freshwater organisms floating into estuaries from streams and lakes. To date 11 manuals have appeared in print and others are in preparation.

Systematic Services

For many kinds of organisms one investigator easily obtains enough specimens in a short time to swamp several identifiers for months. Moreover, there are many more requests than can be filled for service identifications for ecologists, amateurs, public health officials, and those conducting stream and forest surveys; for lists of organisms for impact studies; and for the needs of pollution assessment and monitoring. These, and other economically oriented service needs, have far outstripped the capacity of taxonomists and their assistants to cope with the flood of requests (Irwin et al., 1973). In spite of the fact that many state governments, experiment stations, or agricultural schools employ personnel to provide identification services of species common in their geographic areas, the number of professionally capable systematists is still small. The federal government maintains national identification services for several groups of economically important organisms, such as insects and related taxa, and parasites of domestic and other animals. Some of the federal services provide in-house identifications only, while others serve outside agencies and the general public. Even with these services, nonetheless, identifiers for many taxonomic groups are quite unable to keep up with the current demand for determinations, much less provide for prospective future needs. Some sorting centers have been created for marine organisms, but none makes specific identifications, and lag time is exasperating (Michener, 1970).

In addition to current requests, most taxonomists are faced with a great accumulation of unworked, undetermined specimens which have piled up for years (Schmitt, 1953). Because systematists who are willing to function in a service role are invariably overworked and under-assisted, they are unable to cope with the demands on their time. The needs of other biologists are thus often poorly served, and available comparative collections are frequently inadequately curated for proper study (Irwin et al., 1973).

Traditionally, identifications have been provided free of charge by taxonomists or organizations willing to make them. This practice is patently unfair, and has contributed to the lack of technical assistance to systematists, to the prolonged delay in obtaining identifications, and to the unattractiveness of the service function. It is gratifying to report, however, that this trend is shifting, and some grants are now including funds for taxonomic services.

Most critical in the long view, after all is said and done, is the fact that the service role often prevents systematists from getting on with the urgent research of preparing the basic floras, faunas, and monographs—the very foundation of the service function.

There is thus unquestionably a strong basis for the alarm expressed, especially by organismic biologists, over the service role of systematics to the nation and the future of the field of systematics itself! It is clear that a strong, coordinated, long range, national plan is urgently required.

Members of the Association of Systematics Collections (ASC) have already formulated such a plan called "America's Systematics Collections: A National Plan" (Irwin et al., 1973). This stresses the importance of systematics collections to science, society, and education, and outlines an approach, carefully developed by the newly organized community of systematists, for the recognition and development of systematics collections as an important national resource and service.

Specific goals of the ASC include: (1) management of the national inventory of specimens and associated documentation in museums and herbaria to insure a) permanent conservation of specimens, b) ready access to them and their documentation, and c) space, facilities, and library resources; and (2) addition of new specimens and associated information. Specific service-related aims include (1) make available upon demand specimens or taxon-related information in a variety of useful forms, (2) enable incorporation of specimens and associated data in an information management system, and (3) enable ready access to specimens themselves and to associated documentation and library materials. The ASC is moving ahead to implement these goals. Some of their activities, carried out through a series of ASC Councils, include: (1) identifying systematics collections of importance as national resources; (2) developing standards for systematics collections; (3) implementing electronic data processing in collection management procedures; (4) developing more effective use of systematics collections in the study and resolution of problems affecting the quality of the environment; and (5) developing technical training programs for professional service personnel and their placement.

A major emphasis of the ASC is correct identification of species to indicate environmental changes and their effects on human welfare. The association accordingly includes in its plan a survey of public and private agencies to determine actual or potential availability of resources to support, among other systematic activities, contracts for specific identification services.

Systematic resources in the United States of importance in estuarine biological work also include collections of living specimens. The American Type Culture Collection, for example, is a national identification center in Rockville, Md., which for a fee identifies live viruses, bacteria, fungi, and protozoans. The organization is now establishing a national computerized microbiological strain data center which will permit investigators to compare microbiological data with that at other centers in the country. Another important national research resource is the Culture Collection of Algae at Indiana University, Bloomington. Identification services are not provided because of lack of personnel, but living type cultures of algae are available for a nominal charge.

Non-Specialists and Identification

The non-specialist is usually able to identify and classify only those species which specialists have already described, named, and reported in the scientific literature. Because of the frequent difficulty of use of the original systematic reports by nonspecialists, systematists synthesize the original literature into a form which is more readily applied in identification and classification. These syntheses take the form of illustrated manuals, check lists, taxonomic monographs, and general systematic books. An excellent example of the last category is the recent volume by R. T. Abbott (1974) on the marine molluscs of the Atlantic and Pacific coasts of North America. Others are E. L. Bousfield's (1973) fine publication on the shallow water gammaridean amphipods of New England, and Light's manual on the intertidal invertebrates of the central California coast (Smith and Carlton, 1975).

Because closely similar species may be confused, it is highly desirable that the non-specialist confirm his preliminary identifications by comparing specimens with correctly identified specimens in museum and herbarium collections. This procedure is all the more important as similar and closely related species not listed in publications readily available to non-specialists may be overlooked.

For careful research, comparison alone may not provide the necessary authoritative confirmation. In this case the assistance of a specialist, or an assistant closely associated with the specialist, should be solicited. Identification is not always a simple matter of identifying one standard form of individual. In a series of individuals from many localities, complications may be introduced because of such modifying factors as individual, sexual, seasonal, ontogenetic, and geographic variations, as well as the possibility of intergradation with neighboring species (Schmitt, 1953). Moreover, introduced and immigrant species may be present that answer to the same criteria in a key as do local species. Hedgpeth (1975) informs me that over 50 non-native species occur in San Francisco Bay alone!

Because of the taxonomic complexity of many organisms, and the consequent danger of misidentification, voucher specimens should be made available, preferably in museums and herbaria, whenever possible. These insure that the value of ecological, behavioral, physiological, biogeographic, and other biological work based on identifications will not be reduced due to questions about inaccuracy of determination of the organisms involved (Irwin et al., 1973).

TRENDS IN SYSTEMATICS—SYSTEMATISTS ENDANGERED?

Unquestionably the degree of success of the service function of systematics in future years will be determined by the health of the field of systematics today. It is thus important to review the current state of the discipline.

In Darwin's time systematists enjoyed a high reputation. The turning point in disfavor came about the turn of the century, not because of the work of systematists but because other fields of biology seemed more promising (Hedgpeth, 1961). Systematics then received a substantial stimulus with the creation of the National Science Foundation in 1950. Although increased funding resulted in a multiplication of systematic research, subsequent financial support from all sources has been insufficient to keep pace with the needs of systematics in either basic or applied areas. Consequently, the current resources of the field are inadequate to meet not only present national service needs, but much less the needs of the future.

For one thing, decreasing numbers of students are attracted to careers in systematic biology. The reasons, not hard to find, contribute to the low number of trained systematists: a tight job market and reluctance of many university departments to hire systematists, overshadowing of systematics by such fields as ecology and behavior, reduced amount of available support for graduate students in the form of fellowships, and general deemphasis of systematics in graduate curricula (Humes, 1974). In fact, systematists have been all but excluded from many of the best biology departments in this country (Wilson, 1971). As a result, many teaching systematists are trying, with little success (Steere, 1971), to leave academia and move into museums which seem to have become the last bastion of defense for systematics—which is wrong! (Pawson, 1974).

Because systematics does not occupy a prominent position in most educational institutions, much of the systematic research conducted in the country is done in fragments of time snatched between administrative or teaching duties by biologists whose major responsibilities are nonsystematic.

In spite of the fact that the potential worth of systematics to society is now greater than ever, only a handful of graduate university departments in the United States and Canada are now strong in systematics. These departments have to be associated in some way with research collections to conduct their teaching and research; and whereas several state universities and colleges used to maintain museums with biological research collections, few do now because of funding problems. Default in this area has thus led to surrender of important regional collections to the United States National Museum. The result of this drift in collections has been to remove resource materials from new scholars to some degree and to widen the split between educational opportunity and young biologists who could participate in this discipline. Many who become taxonomists, therefore, do so in spite of these difficulties, or are self-trained (Mosquin, 1971; Watling, 1974; Williams, 1974).

Systematists at the doctoral level require many years of training. Most rarely wish to devote full time, or even part time, to the service aspects of systematics, particularly since such services are not professionally satisfying and have seldom been financially compensated. Hopefully, with growing national recognition of the importance of systematics, more systematists will be encouraged to participate in service oriented investigations; the resulting service resources (keys, manuals, monographs, computer programs, and so on) then being turned over to technical taxonomically trained assistants to carry out the service activities. It is important that the significant role of taxonomic assistants be fully recognized, and that they become the major working force in taxonomic service centers under the direction of professional supervisors.

Since the number of pure research positions in systematics is limited and most systematists earn their living as teachers, curators, members of identification services, or in other branches of biology, the borderline between systematists and other biologists has blurred. This is providing opportunity in systematics for biologists of varied interests (Mayr, 1969). Many ecologists are a good example. Because of the scarcity of systematists, identification has fallen increasingly on the ecologist, and as a consequence some have become highly proficient in the systematics relating to their field of research. The blending of systematics with closely related disciplines, both as pure science and in its application, augurs well for the future of systematists. So does the growing appreciation of the correct image of the modern systematist; that is, one who concerns himself not only with preserved specimens in collections, but who also works in the field and in the laboratory studying whatever phase of morphology, physiology, ecology, behavior, biogeography, and life history contributes to a fuller quantitative understanding of the likenesses, differences, groupings, and evolution of the species of his specialty (Turner, 1974). Mayr (1969) notes that the systematist has every reason to be optimistic about the future of his field. The laudable efforts of the Association of Systematics Collections may help to materialize this optimism. For the moment, though, we have to agree with Redfield's (1958) observation for an earlier period, that "The line of advance in taxonomic knowledge is held by a perilously thin force of specialists."

With growth and strengthening of biological research, has come increased usage of systematics collections. Researchers in increasing numbers are visiting the few systematics collections in their specialties. The number of loans of specimens similarly has grown. Burgeoning collections and loan requests are outstripping staff capabilities. Nearly every major institution responsible for major systematics collections is crowded, and space is inadequate for effective research and efficient care of specimens. A further depreciating factor is the prevalent shortage of clerical and subprofessional help, especially in institutions having ambitious systematic programs and limited finances (Schmitt, 1953). It is thus no surprise that systematics collections are deteriorating. To all of this must be added the factor of inflation which results in lowered income.

Summary.—Even though requirements for identification of estuarine and coastal organisms have greatly accelerated, present trends in systematics appear bleak indeed.

Relative to the population growth of the country, (a) there are fewer highly trained systematists; (b) there is a significant decline in the number of practicing taxonomists (Higgins, 1974); (c) there is less financial support for them and for systematic activities in all institutions; (d) there are fewer positions and (e) training opportunities; and (f) there is a scarcity of journals in which to publish (Gosline, 1974).

It is increasingly difficult to have organisms identified; capable systematists are so much in demand that they give service only to a selected few, generally with preference to those who furnish specimens which remain in their collections or new species that are to be described (Allen, 1974; Tarzwell, 1974).

The fate of biological collections in colleges and universities depends to a deplorable extent upon the research emphasis of the moment. As responsible personnel move to other institutions, collections are left in grave danger, or they are turned over to the large museums and herbaria of the country. These changes invariably occur without increase of their supportive resources. As a consequence these large institutions are increasingly charged with carrying out and supporting systematic biology. At least one danger of this trend is the weakening of instruction in systematic biology and thus the balanced and orderly development of the science of biology itself (Schmidt, 1952).

Progress has been made in some aspects of systematics, but serious setbacks have occurred in others. For example, there has been increased emphasis on the taxonomy of both phytoplankton (especially nanoplankton) and zooplankton (especially larval forms and their developmental stages), but the systematics of nematodes which appear to be the most abundant of the metazoans and are probably the most diverse in number of species, has hardly progressed from the status of 19th century science (Murphy, 1974).

There is a definite, healthy trend toward numerical taxonomy and phenetics to define species assemblages, but a marked increase in casual identifications in applied systematics often by ecologists engaged in biomass and community structural studies (M. Abbott, 1974).

Finally, Steere (1971), writing about institutions which house biological systematics collections, reports that in the previous three years, operating expenses almost doubled, and endowment returns and contributions halved. Predictably this has led to substandard salaries, deterioration of personnel strength (because of unchanged staff size in the face of swelling collections and increased demands for service), reduction of activities, and deferral of expansion. This situation is totally unacceptable if modern biology is to develop in these institutions and they are to fulfill their service roles in applied systematics!

Water Quality Legislation and Systematics

Water quality legislation assures "the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife" in any body of water into which, for example, thermal discharge is to be made (Federal Water Pollution Control Act, Amendments of 1972, Public Law 92-500, Section 316(a); see also Section 102(a) and Hedgpeth, 1973). The legislation implies the need for identification and classification of organisms, both target and non-target species, involved in analysis of the biological impact of pollutants. By way of example, consider the voluminous reports which have appeared on such subjects as ecological effects of pesticides on non-target species (Pimentel, 1971) and data on water quality criteria (Batelle, 1971; NAS-NAE, 1972). As of this date, however, this emphasis of the federal legislation has not resulted in conspicuous financial support for systematic work on any of the important taxa.

It is certain that requirements for identification of biota will not only continue, but will increase, because of the escalating concern of many agencies and the public with problems and issues of environmental quality. Emphasis at the moment reflects needs anticipated and created by the energy crisis. Other issues concern mercury, lead, asbestos, PCB's, NTA, and oil spills (for example, see Eisler, 1973). It is certain new concerns will emerge in the future. Specimens in museums, herbaria, and live culture collections, and those made to meet immediate needs, will continue to provide baseline data prior to and following environmental alterations (Allen, 1974). Organisms involved must thus be correctly identified; if not, costly mistakes can occur. It is consequently with dismay that one reads: "The taxonomic level to which animals are identified depends on the needs, experience, and available resources" (Weber, 1973).

Adequate environmental assessment cannot be obtained without the resources of systematics collections. The Environmental Protection Agency has made a preliminary effort to contribute toward improving the quality of data upon which environmental decisions are based (see, for example, the identification manuals of Correll and Correll (1972) and the Smithsonian Institution (1972–1973)), but unfortunately these efforts are giving way increasingly to mission oriented and mandated activities (Allen, 1974). Also note that monitoring of biota was demanded in licensing by the Atomic Energy Commission, but there has been no visible increase in the demand for systematists resulting from these requirements (Higgins, 1974).

Man is an organism, of course, but since he does not generally submit to being used as a barometer of environmental conditions, he delegates this responsibility to other forms of life. This is a weighty responsibility and necessitates that the taxonomic position of his substitutes be solidly established for purposes of comparison and prediction!

CONCERNS AND CONCLUSIONS

Basic and applied environmental research and its application to such practical problems as pollution, have grown far more rapidly than the supporting base of systematic biology. As a consequence of this deficit and the conditions described in this paper, systematists find themselves in a paradoxical quagmire. Thus, though willing, they are unable adequately to fill the needs of environmental biologists, pollution scientists, and others for systematic services. The concerns may be summarized as follows:

1) There is an increasing shortage of systematists to handle and supervise identifications and classifications; as a consequence, more and more inadequately trained persons are performing this service;

2) There is an insufficient number of systematists to conduct the basic research necessary to produce the systematic tools required in applied systematic biology;

3) Identification and classification aids are inadequate or insufficient for most taxa, and are entirely missing for others;

4) The number of taxonomically well-trained technicians to relieve systematists of the work of routine identification is grossly insufficient;

5) Compensation to systematic specialists for taxonomic services is generally nonexistent, a lack foreign to professional services in other scientific and engineering fields;

6) There is a total absence of current directories of systematic specialists, identification service centers, identification aids, and a national computerized storage-retrieval system for the systematic resources of the nation;

7) Both young and experienced systematists find it increasingly difficult to obtain positions in their fields of specialization;

8) Young people are unable to obtain training in systematics in most colleges and universities where the field receives decreasing emphasis and support;

9) Valuable representative collections from environmental studies are discarded or lost, and no voucher specimens are reposited in museums and herbaria for future reference;

10) Environmental agencies have paid lip service to the importance of systematics in environmental work, but have not provided the financial support necessary to help prepare systematics more effectively for this role;

11) Most museums, herbaria, and living collections receive inadequate financial support and are understaffed, with the result that systematics collections are receiving insufficient care, are deteriorating, and the service function is suffering—the problem being seriously compounded by inflation.

The most pressing systematic service needs at the moment are (a) well trained technicians, (b) systematists with the time to supervise them, (c) identification aids, and (d) funds to help systematists carry out their functions and elevate systematic biology to the position where it can more effectively contribute to science and to society.

It is imperative that everything possible be done, not only to conserve the human and material systematic resources already existing, but also to support and encourage further development of these resources in a hospitable climate, appreciatively recognizing the economic and intrinsic worth of their contributions. The tasks facing systematists are unquestionably monumental and long-term.

RECOMMENDATIONS

The following recommendations are offered to maximize the service role of biological systematics in the assessment of the effects of pollution on the biological utilization of estuaries and coastal waters in the United States:

(1) A major, national, coherent force working in behalf of systematics in the country is the Association for Systematics Collections. The ASC estimates that it will cost $63.3 million in the next five years to effect its national plan for the conservation and development of systematics collections as a national resource and service (Irwin et al., 1973). The various councils of the ASC are now preparing proposals for financial support to carry out the plan. We urge federal and private agencies to look with favor on these proposals. A unique feature of the ASC plan is its integrated national character, a necessary attribute to provide systematic services in any estuary or coastal area in the country. Support must go to aid in the development of aspects of the plan as a whole, rather than for parochial units of restricted regional interest. In view of the increasing number of persons who are making professional identifications without the advantage of adequate training, we further urge the ASC to establish a roster of persons qualified to make service identifications in the various groups of organisms.

(2) In the face of growing, critical, environmental problems in estuaries and coastal waters, institutions and agencies will accelerate their search for

financial support through grants and contracts to attack these problems. In the interest of aiding the service aspects of systematics, we urge funding agencies to look favorably upon requests involving: (a) compensation to systematic specialists in the private sector for identifications and confirmation of identifications; (b) proper curation of biological research collections resulting from environmental and other broad investigations to serve as voucher specimens; (c) services for taxonomically trained assistants; (d) enlargement of identification service centers in museums and universities, including training of taxonomic technicians to handle specimens from major pollutional surveys; (e) fellowships for advanced training at those major museums and universities having faculties in evolutionary biology, in combination with ecology, comparative physiology, or other organismic biology; (f) support of systematists in governmental agencies and elsewhere dealing with whole organisms, giving them time to develop their systematic specialties and to contribute to the upgrading of practical systematics through the preparation of basic and applied systematic resources.

(3) A serious void in identification publications is comprehensive illustrated identification manuals. Accordingly, we urge funding of a comprehensive, illustrated, coastal flora and fauna series for each major coastal region of the United States which would invite the talents of the community of systematists in the preparation of each series. A minimum of $25,000 will be needed per year for each of the three series already in progress on the east coast, and at least similar amounts will be necessary for a new series for the gulf coast, and another for the west coast—a total of $725,000 for the first five years.

(4) A number of persons of considerable competence as systematists, many at the doctoral level, unable to obtain positions either in museums or in universities, are now supervising environmental departments of engineering and power companies. Their training as systematists has thus been a waste to society. We endorse Hedgpeth's (1975) recommendation that each power and engineering company hire a systematist specializing in a different taxonomic group to provide identification service for a reasonably natural geographic region. Thus on the Pacific coast one power company might provide service for polychaetes, another for crustaceans, and so on. Nominal fees should be charged for the service.

(5) A major long-term research effort, to be measured in decades, is still required before the full extent to which systematic knowledge can significantly aid in the identification and control of pollution is known. Moreover, completion of the task of identification of most undescribed species will require several more generations. We thus urge that adequate support for systematics be sustained for many years to come, allowing the maximum return on the investment in terms of basic systematic knowledge and taxonomic services.

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BACTERIA AND VIRUSES—INDICATORS OF UNNATURAL ENVIRONMENTAL CHANGES OCCURRING IN THE NATION'S ESTUARIES

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ABSTRACT

Microorganisms are useful indicators of alterations in the natural environment. As presently employed, however, "indicator organisms" such as fecal coliforms and total coliforms have severe limitations. Other organisms have been proposed in recent years as potential indicator organisms, viz., streptococci, clostridia, and pseudomonads. The indicator organism concept is reviewed and recommendations for future studies are made. In particular, detection, isolation, and identification of viruses, effects of pollutants on the natural microbial flora, and reevaluation of microbial indicators are critical areas requiring research.

INTRODUCTION

The bacteria, yeasts, and fungi naturally present in waters and sediments play an essential role in the mineralization and cycling of nutrients necessary for normal plant and animal growth. A variety of microorganisms may appear in given ecosystems from time to time because of the ubiquity of many bacterial species; in general, the normal flora of the aquatic habitat is distinguishable from bacteria associated with warm-blooded animals and man. Moreover, the numbers and types of bacteria present in the natural habitat are generally in balance so that conditions are stable within recognizable, normal levels. When abnormal conditions occur, changes in the microbial populations will ensue. For example, with pollution from domestic or farm animals, influx from wastewater treatment plants, and so forth, the number of bacteria of animal or human origin increases. Hence, a hazard to man may develop.

Estuarine eutrophication and coastal pollution pose increasingly serious environmental problems. Nutrient loads in estuaries are based on watershed characteristics, influent stream concentrations, and overall watershed management policies. The role of microorganisms, in particular the bacteria, is to break down the dead organic material and wastes so that organic nutrients necessary for plant growth are provided and organic wastes are removed by mineralization. Thus, the role of the bacteria, yeasts, and fungi, is, simply stated, to keep the wheel of nature turning by recycling complex organic and inorganic materials. Nutrients, in moderation and in proper balance, permit normal algal productivity which, in turn, supports animal life.

Changes in environmental conditions may cause more subtle effects on the normal microbial flora, leading to such conditions as increased disease in many resident fish species or unpleasant anoxic conditions arising from hydrogen sulfide production.

INDICATOR ORGANISMS

In the case of microorganisms, indicators are usually considered in relation to human health risk. The most common forms of water-borne human disease are caused by bacteria excreted from the intestines of man and warm-blooded animals. Fecal contamination is recognized as dangerous. However, pathogens normally are present in small numbers and are difficult to culture and identify. Thus, the more easily identified organisms that are commonly and specifically present in feces serve as indicator organisms. The most widely used are the so-called coliform bacteria, with *Escherichia coli* or the less specifically fecal coliforms being tested for in most cases.

Thus, for well over a hundred years, bacteria have been used as indicators of unnatural or undesirable environmental conditions, mainly as indicators of human health hazards, i.e., warning signs that potential human pathogens may be present. In 1885 Escherich described the bacterial species he believed to be characteristic of human feces and, therefore, an indicator of fecal pollution. The bacterial species of Escherich is now classified in the

Escherichia-Enterobacter group and comprises, with other species, the complex now referred to as the coliform group. These organisms are to this day the indicator microorganisms employed by authorities in determining rate and extent of pollution from domestic sewage.

Eijkman, in his studies carried out over 70 years ago, recommended an elevated temperature incubation test that gave a positive reaction with fecal coliform organisms and a negative reaction with those of non-fecal origin (Eijkman, 1904). The Eijkman test procedure is the basis of the EC test, which is widely used to detect fecal coliforms. Unfortunately, no test is available for differentiating coliforms of human versus animal origin. The Eijkman test, however, does indicate fecal coliforms. The generally accepted principle is that the presence of fecal coliforms indicates the potential presence of disease-producing microbes (Kabler et al., 1964).

Present methods depend on enumeration of lactose-fermenting bacteria by an MPN procedure and further biochemical testing to establish whether these organisms are coliforms, fecal coliforms, or *E. coli*. General standards have been developed to relate the quantitative occurrence of these various types to presumed acceptable or unacceptable levels of fecal contamination (Hoskins, 1934; Geldreich et al., 1962).

Streptococcus spp. known as enterococci occur in the gut of warm-blooded animals and man. Studies of streptococci in water and sewage have shown that these organisms can serve as indicators of fecal pollution. The sanitary significance of fecal streptococci has been clarified and these bacteria can now be efficiently and accurately enumerated in water samples. All of the species or types of fecal streptococci found in feces of human beings and animals can be isolated from sewage and water contaminated with sewage, including estuarine and coastal waters (Bartley and Slanetz, 1960). A definite relationship between the densities of coliform bacteria and enterococci in sewage has long been known (Litsky et al., 1953). In fact, an increase in the coliform index is generally followed by a predictable increase in the enterococcus index, with a direct relationship between the numbers of coliform bacteria and enterococci. Unfortunately, enterococci are found elsewhere in nature, occurring on plants, in dairy products, and so forth, so that sources of these microorganisms must be carefully scrutinized at each time of assessment (Mundt, 1964; Geldreich et al., 1964). Because of their resistance to adverse conditions, enterococci are fairly widespread. Therefore, one must expect, and deal with, higher "natural" levels. The isolation of enterococci from nature has been enhanced by improved methods and media for isolation. For example, azide dextrose broth, used as a presumptive test, and ethyl violet azide broth, a confirmation test, permit two to three orders of magnitude improvement in the isolation and identification of enterococci (Litsky et al., 1955).

A variety of pathogenic microorganisms may be present in the feces of warm-blooded animals, viz., *Brucella*, *Salmonella*, *Shigella* spp., *Mycobacterium tuberculosis*, *Pasteurella*, *Leptospira*, *Vibrio cholerae*, *Entamoeba histolytica*, and various enteric viruses. Most of these genera noted are present in the feces of diseased animals. Hence, the main factor involved is the occurrence in a population and shedding of the microorganisms into water via feces. Thus, the density of pathogens in the aqueous environment is affected by a variety of factors: (a) type and degree of sewage treatment; (b) ability of microorganisms to survive the effects of antibiosis, predation, and chemical nature of the water; (c) dietary habits and socio-economic status of the community; (d) the prevalence of specific disease in the community; (e) endemic conditions in the human and animal population; and (f) existent carrier rates in the population (Brezenski and Russomanno, 1969). Therefore, the introduction of specific pathogens via sewage or runoff into estuaries and coastal waters is not constant, but rather tends to be intermittent. With the uneven microorganism distribution in water, coupled with effects of dilution and environmental parameters, such as temperature and salinity, the density and distribution of pathogenic microorganisms has resulted in the search for indicator organisms, as opposed to looking for the individual pathogen. More accurate and simplified techniques for the isolation of *Salmonella* have been developed in recent years so that confirmation of *Salmonella* can be achieved (Cheng et al., 1971). Despite the fact that detection methods for *Salmonella* have been improved, they are still likely to be missed.

Where the bacteriological quality of the water is poor, fecal coliforms and salmonellae can be isolated. Often in estuaries and coastal waters, wild fowl will contribute to the salmonellae population load (Strobel, 1968). Salmonella, in recent years, have been directly isolated from polluted tidal estuaries, but at low percentage recovery, i.e., 1 to 200 fecal coliforms (Brezenski and Russomanno, 1969). Nevertheless, the prevalence of *Salmonellac* is greater than previously thought to be. Factors, such as salinity, temperature, and others associated with the saline environment cannot be depended upon to eliminate such pathogens. Greater survival of salmonellae and fecal coliforms in shellfish, when the water temperature reaches below 5°C, has been observed by several workers. Clearly, isolation of salmonella from a polluted marine environment has been improved by application of better techniques and enrichment media (Grunnet et al., 1970). However, these pathogens, because of the complexity of the methods required for isolation and identification, are not ordinarily searched for in an analysis of water quality.

More recently the anaerobic bacteria, i.e., the *Clostridium* spp., the acid-fast bacteria, i.e., *Mycobacterium* spp., and yeasts have been suggested as indicators of sewage pollution. Selective procedures for these organisms are now being developed. Rapid isolation procedures are not yet available. The major *Clostridium* species in polluted marine sediments have been shown to be *Cl. perfringens*, *Cl. bifermentans* and *Cl. novyi*, these representing 58 percent of the population and reflecting the representation of Clostridial spp. in sewage (Matches et al., 1974). *Cl. perfringens*, because it is more sewage related, appears to be of useful sanitary significance in cases of high pollution levels. Similarly, the densities of yeasts in sewage and in polluted waters have been shown to be high, with *Candida tropicalis*, *Trichosporon cutaneous*, and *Rhodotorula* spp. potentially serving as useful indicator organisms. In fact, the pathogenic yeast, *Candida albicans*, has been shown to be a good indicator of recent human sewage pollution (Ahearne, 1973).

Clearly, bacteria and viruses serve as indicators of health in estuaries and coastal waters. Many studies over the years have shown that under natural conditions, i.e., in areas untouched by the activities of man, a relatively stable total microbial population occurs in water and sediment. Under conditions of imbalance, microorganisms will achieve very high total numbers and frequently under such conditions will cause foul odors, unacceptable bottom or sediment conditions, slimes fouling fish nets and floating objects, and depletion of dissolved oxygen in the water, thereby affecting fish and other organisms. In balance, microbial populations perform a necessary function in estuaries and coastal waters. Out of balance, the viruses, bacteria, yeasts, and fungi become nuisances and threaten the health of humans and of desirable plants and animals.

Microbial quality changes in estuarine and coastal ecosystems may prove to be valuable indicators or "early warning systems." However, in the case of ecosystem components, such bacterial groups as the sulfur bacteria, iron bacteria, blue green algae, and so forth, have not yet been sufficiently studied to be easily isolated and identified. Hence, their use as indicator organisms is limited, particularly since ecosystem monitoring on a long-term basis, which would help to clarify the role of these organisms, is lacking.

Improved Detection of Indicator Organisms

Detection of indicator organisms has improved considerably in recent years with the application of methods such as membrane filters (American Public Health Association, 1971; Presswood and Brown, 1973) and development of techniques employing nonfluorescing membrane filters and specific fluoresceinisothiocyanate-labeled antiserum (Guthrie and Reeder, 1969). Fluorescent antibody methods for detection of *Streptococcus faecalis*, *Escherichia coli* and *Salmonella* spp. are now available, improving speed for processing samples over conventional water quality tests, without loss of reliability (Abshire and Guthrie, 1972).

In the case of the fluorescent antibody, techniques pertaining to the pathogens are more advanced than for the indicator bacteria, although fluorescent antibody methods for the detection of fecal streptococci have been developed. Recent work has demonstrated the applicability of the fluorescent antibody technique employing commercially available antisera (Pugsley and Evison, 1974). This, no doubt, will usher in a new era for the use of fecal streptococci in conjunction with other indicator organisms.

Problems with the Indicator Organism Concept

Confidence has been decreasing in the significance of the coliform group as an indicator of fecal pollution. In recently reported epidemics, pathogens have been isolated from waters which, based on coliform standards, should have been safe. *Salmonellae* have been isolated from water supplies containing less than 2.2 coliforms per 100 ml. A number of such incidences where *Salmonella* and enteric viruses have been isolated from waters containing few detectable fecal coliforms have been documented (Bonde, 1974; Dutka, 1973; Fugate et al., 1975). The ability of coliforms to multiply in nutrient enriched receiving waters has been observed. The sanitary significance of fecal coliforms in the environment has been considered by a number of investigators (Geldreich, 1966). Convincing evidence has been presented, showing that viruses are more resistant to chlorination than bacteria. Rates of growth and die-off of both *S. typhimurium* and coliform organisms have been found to be different under varying environmental conditions. Furthermore, conditions causing large reductions in coliforms do not always show correspondingly reduced numbers of *Salmonella* (Dutka, 1973).

The shortcomings of the coliform group as an indicator of pollution have led to the increased desirability of employing the streptococci as indicators of recent and dangerous pollution. The fecal streptococci rarely multiply in water, as some of the coliforms have been found to do. Thus, they offer some advantages as indicators of recent fecal pollution. Also, it has been suggested that domestic sewage pollution can be differentiated from animal wastes, land runoff, and storm water pollution by fecal coliform-fecal streptococcus ratios (Geldreich, 1972).

In general, the fecal streptococci are more resistant to the natural water environment and to purification processes than the coliforms or fecal coliforms. At points distant from the original source of pollution, the fecal streptococci are often the only indicators of the fecal nature of the pollution. Studies have shown that the survival of fecal streptococci parallel the survival of enteric viruses better than the coliforms (Cohen and Shuval, 1973). It has been suggested by some workers that the fecal streptococci may, in some cases, provide a better estimate of the probable virus content (Cohen and Shuval, 1973).

Dissatisfaction with the fecal coliform and fecal streptococci has led to a search for other, better indicators. Coliphages (bacterial viruses) have been suggested as indicators of sewage pollution. However, no consistent relationship is observed between coliform and coliphage levels (Hilton and Stotzky, 1973). Although the complexity of the bacteriophage method and time required before final results are available discount their use as indicators of fecal pollution of water, bacteriophages can serve well as models for detection of enteric viral pollution of water and in epidemiological applications (Scarpino, 1974).

Pseudomonas aeruginosa is slowly gaining favor as an indicator of water quality, especially as an indicator of potential upper respiratory tract infections (Foster et al., 1971; Kenner and Clark, 1974).

Relatively recent approaches to estimating bacterial quality of water are uptake of phosphorus, using radioactive phosphorous (Khanna, 1973), and assay for fecal sterols for water pollution indication. The intestinal bacterial flora is associated with production of characteristic fecal sterols discharged in feces (Martin et al., 1973). Fecal compounds, in particular coprostanol and cholesterol, thus, have been examined and a coliform-coprostanol relationship has been reported. However, a consistency in the relationships from the data presently available has not been observed (Dutka, Chan and Coburn, unpublished data). Fecal sterols may well prove useful in the future as pollution indicators, but the method will require substantial developmental research before proper evaluation and application are possible.

Natural Estuarine Microbial Communities

Microorganisms autochthonous to a given estuarine system play a fundamental role in mineralization and cycling of nutrients. Estimation of the microbial biomass comprising the natural flora of estuaries can be accomplished by direct counts and morphological observations using acridine orange staining and epifluorescence illumination of the bacteria collected on non-fluorescent membrane filters. Measurement of the activity of microbial populations directly in the environment can also be accomplished using methods such as uptake rates of radioactively-labeled organic substrates (Wright, 1973). The use of ATP to measure standing crops of microorganisms is widely accepted (Holm-Hansen, 1969) and the ATP method offers promise as an indicator of microbial activity.

The role of bacteria in the detrivore food chain is only beginning to be understood (Hamilton, 1973; Rosswall, 1973). Effects of pollutants on these natural processes require extensive study since very little information, relatively speaking, is presently available.

Deterioration of Coastal and Estuarine Waters

Many studies have shown that coliform bacteria introduced into tidal, coastal, and deep sea waters disappear rapidly. A large number and variety of factors have been shown to be involved in the die-off of coliforms, especially *Escherichia coli*, in seawater. Dilution, bacteriocidal action of seawater, grazing by zooplankton, adsorption on estuarine and coastal sediments (Ketchum et al., 1952), salinity, effect of heavy metals in seawater (Jones, 1963; 1971), lysis of coliforms by indigenous marine bacteria such as *Bdellovibrio* spp., and bacteriophages (Mitchell et al., 1967; Carlucci and Pramer, 1960), low nutrient levels in seawater (Jannasch, 1968), daylight (Pike et al., 1970) and temperature have been offered as explanation for the die-off of *E. coli* in seawater and for the absence of fecal coliforms in ocean locations far from land. Nutrients have a marked beneficial effect on the survival of *E. coli* in seawater. Some nutrients, such as cysteine, very likely act by chelating metal ions in seawater (Scarpino and Pramer, 1962).

Furthermore, above certain BOD levels, viz. 1–10 mg/l initial BOD, seawater will temporarily lose its toxicity and the maximum bacterial density becomes dependent on the initial BOD. In fresh seawater with BOD levels of 10 to 120 mg/l, the relationship between the log of the maximum bacterial densities and the initial BOD appears to be linear. Thus, by themselves, total and fecal coliform bacteria may not be reliable indicators of the degree of recent fecal pollution in seawater because, given sufficient nutrient levels, the bacterial density will increase (Savage and Hanes, 1971). Growth of coliform bacteria, isolated from soft-shelled clams, in estuarine water has been demonstrated (Lear, 1962). The conclusion which can be drawn from the data available is that the various factors in seawater which, under clean, unpolluted conditions, will act to eliminate coliforms from estuarine and coastal waters cannot be depended upon in waters receiving heavy nutrient input. In fact, increases in coliform populations will occur and it is possible that survival of pathogens may be enhanced.

A signal to this effect is the relative ease with which antibiotic-resistant coliforms can be isolated from estuaries and coastal waters (Colwell and Sizemore, 1974; Feary et al., 1972). Many of these bacteria have been shown to harbor R factors carrying multiple antibiotic resistance which could be transferred to sensitive *Salmonella typhimurium*, *Shigella dysenteriae*, and *E. coli*. Of serious concern is the fact that these bacteria are isolated from shellfish waters. Furthermore, chloramphenicol-resistant bacteria of fecal origin may pose a particular health hazard, with reference to R factors which carry resistance determinants to chloramphenicol. Transfer of chloramphenicol resistance to *Salmonella typhi*, a water-borne organism, or to *Vibrio parahaemolyticus*, would make treatment of typhoid fever or *V. parahaemolyticus* food poisoning more difficult. It would appear, therefore, wise for sanitary quality measurements of shellfish waters to include estimates of chloramphenicol-resistant fecal coliforms. An important conclusion of the work on antibiotic-resistant types found in rivers, estuaries, and coastal waters is that the R + *E. coli* comes from urban sewage (Smith, 1970).

The coincidence of infectious disease in fishes with stress caused by temperature, eutrophication, sewage, industrial pollution, and pesticides has been documented (Snieszko, 1974). Estuaries and coastal areas affected by pollution expose the fish in these areas to frequent stresses, i.e., unfavorable or fluctuating water chemistry, organic pollutants, and so on (Wedemyer and Wood, 1974). If the occurrence of stress coincides with the presence of pathogenic microorganisms, outbreaks of disease will occur. Interestingly, in treated sewage the number of coliforms is reduced, but in the bacterial population, the coliforms appear to be replaced by *Aeromonas* which multiply in the slime lining of the pipes carrying the sewage (Heuschmann-Brunner, 1970). The quantity of *Aeromonas* in water can be related to the degree of pollution. Many *Aeromonas*, *Pseudomonas*, and *Vibrio* species are bacterial fish pathogens. Marine fishes in areas exposed to pollution have been reported to show exophthalmus, open external sores, epitheliomas, and papillomas. In fishes experimentally exposed to the polluted water, skin hemorrhages, opaqueness of eyes, and blindness were observed. In terminal stages fluid accumulated in the body cavity and internal hemorrhaging occurred. *Aeromonas*, *Pseudomonas* and *Vibrio* were isolated from the diseased fishes. All strains isolated from marine fishes were halophilic (Snieszko, 1974). The conclusion, therefore, is that there is a relationship between incidence of disease in fish populations and pollution of estuarine and coastal waters with domestic and industrial sewage. A weakening of the fish, with subsequent invasion by microorganisms, causing disease and/or death, appears to be related to pollution. Unfortunately, in several incidences, widespread distribution and prevalence of *Aeromonas* spp. was noted with a general lack of coliforms and other sewage-related organisms. Recovery of "almost pure cultures of *Aeromonas* spp." from the effluent of sewage-treatment plants has been observed, particularly in estuarine water (Snieszko, 1974). It can only be concluded that the incidence of diseases of aquatic animals in which *Aeromonas* plays an important role will increase. The additional factors of low dissolved oxygen, high temperature, and pollution by chemicals, such as pesticides, petroleum, and heavy metals, must contribute to outbreaks of infectious diseases of aquatic animals. In fact, fishes although long considered important animals for assaying water pollution are becoming valuable indicators of the environmental health of bodies of water. The Chesapeake Bay is highly polluted by every type of waste. Some of the waste causes eutrophication, with increase of bacteria and algae and oxygen depletion. Fish kills are a frequent occurrence, particularly in summer months. Epidemics causing massive mortalities of fish in Chesapeake Bay have been recorded (Snieszko, 1974).

Deterioration of estuarine and coastal waters can be detected in increased nutrient input, with concomitant rise in indicator or noxious microorganisms, and in increased prevalence of disease among components of the natural biota, especially the commercial fishes.

PROBLEM AREAS

Indicator Organisms

The value of the coliform test as the principal microbiological criterion for sanitary quality of estuarine and coastal waters is a controversial issue. *E. coli* (Type I) appears to be the most reliable indicator of fresh fecal pollution, rather than total coliforms. It is questionable whether coliforms can be regarded as true indicators of fecal pollution at all (Bonde, 1974).

Results obtained from Most Probable Numbers (MPN) measurements have not been sufficiently examined to determine the variability of MPN data. Results obtained from the same area at short intervals of time, i.e., hours, need to be examined critically. If such results are extremely variable, the value of monitoring MPN on daily or weekly intervals is highly doubtful.

There is no single test for the coliforms. Since most of the *E. coli* strains ferment lactose, with production of acid and gas, this characteristic is useful in presumptive, quantitative determinations. Unfortunately, recent work in microbial genetics has shown that not all strains of *E. coli* are able to ferment lactose. Furthermore, this characteristic is not restricted to *E. coli* and may be found in other related bacteria often present in polluted waters. Hence, false presumptive tests are not infrequent. Another difficulty is that coliforms may be affected by their stay in water or sediment and may grow slowly or even lose some of their "typical" characteristics; hence, difficulties in isolation, identification, and enumeration are encountered.

Relatively high occurrence of "false-positives" in MPN estimates of fecal streptococci in estuarine and marine waters has been reported (Buck, 1969). In heavily polluted marine waters, false-positives are not a problem. Mainly in estuarine or marine waters of low or varying salinity, all positive tubes need to be examined microscopically for the presence of nonstreptococcal forms. In fact, an indigenous population of false-positive microorganisms may exist in coastal waters.

Indicator microorganisms other than coliforms also pose problems. *Pseudomonas* spp. are widely distributed in nature. Determinations of *P. aeruginosa*, a known pathogen for man and warm-blooded animals, have been suggested for estuarine waters where high water temperatures and available nutrients can allow growth of this microorganism. *Aeromonas*, fecal streptococci, *Clostridium perfringens*, *Bifidobacterium*, *Bacillus*, *Thiobacillus*, and direct demonstration of *Salmonella* spp. have all been suggested as indicator organisms. A conclusion that can be drawn from the data available in the literature is that all of these indicators should be considered and that more than one indicator organism should be examined. That is, two or more indicator species should be enumerated to improve the reliability of estimating pollution and/or human health hazard.

Survival of pathogens and indicator organisms in estuarine and marine water and sediment is an important problem. Fecal streptococci are supposed to indicate recent fecal pollution and *Cl. perfringens*, because of its spore-forming capacity is considered to be highly resistant, hence of longer survival in nature. Coliforms and *Salmonella typhi* often survive in sediment much longer than in the overlying water. The distribution in mud reflects the effluent flow pattern in the overlying water, with much higher densities of coliforms found in mud. Salmonellae can be isolated from bottom sediments with far greater frequency than directly from the overlying water (Van Donsel and Geldreich, 1971; Hendricks, 1971). However, it should be pointed out that the mud-water interface is not a static system. Currents, storms, seasonal turnovers, and dredging operations can shift sediment, scattering it widely. Such redistribution creates the additional hazard of recirculation of older pollutants in lower layers of sediment. This, coupled with the fact that sediment bacteria are part of the diet of tubificid worms and other sediment-residing biota, provides a mechanism of concentration and transfer of coliforms and potential pathogens among the indigenous fauna (Wavre and Brinkhurst, 1971).

Survival of fecal coliforms and fecal streptococci varies according to season. During the summer months, fecal coliforms can survive slightly longer than fecal streptococci. During the autumn months, survival is about the same and in spring and winter, fecal streptococci may survive much longer than fecal coliforms. Within bodies of water, thermal transitional zones may create bacterial gradients, especially along inshore areas, acting to confine nutrients, bacteria, and nuisance algal growths to the nearshore area. One of the potential hazards of such a thermal barrier, notably in estuaries, is that effluents discharged into a nearshore area are not diluted, as would occur under normal conditions, but are contained by the barrier effect of a thermal bar (Menon et al., 1971). Factors influencing the survival of enteric indicator organisms have been summarized in a recent symposium (Gameson, 1974).

Viruses

During the past decade, there has been worldwide interest and concern that significant levels of viruses are being transmitted through potable and recreational water. Conclusive evidence for the transmission of enteric viruses via this route lies in outbreaks of infectious hepatitis, where sanitary practice or water treatment has broken down or contaminated shellfish have been consumed (Berg, 1973). The opinion that viruses in estuaries and coastal waters pose a threat to human health can be justified by the following facts. Most enteric viruses are more resistant than indicator bacteria to inactivation by water disinfectants. Infectivity tests have shown infection can be caused by one poliovirus TCD_{50} unit (Berg, 1971).

A consistently high endemic level of infectious hepatitis has occurred in the U.S. with the concomitant knowledge that the infectious hepatitis agent is relatively resistant to inactivation in the aquatic environment. Sporadic outbreaks of nonbacterial gastroenteritis suspected of being waterborne have occurred, coupled with a most likely high endemic level of the disease. Finally, surface-water domestic pollution has increased to the point that direct recycling of wastewater and reclamation of estuarine waters is very nearly a reality in the case of some water systems (Akin et al., 1974). Clearly, the danger of water transmission of enteric viral disease is great enough to warrant the more careful consideration viruses are now receiving.

More than 100 new human enteric viruses have been described in the 25 years since the advent of viral propagation techniques using tissue cultures (Scarpino, 1974). All of these enteric viruses are known to be excreted in quantity in the feces of man, including enteroviruses (poliovirus, coxsackievirus, and echovirus), infectious hepatitis, adenoviruses, and reoviruses. Viruses do not multiply outside of living susceptible cells; hence, human enteric viruses can be expected to decrease in numbers with time, even when nutrient levels are high. However, the major question is how long will human enteric viruses survive when discharged into estuarine and coastal waters. The presence of enteric viruses in estuarine and ocean waters has been amply documented (Metcalf and Stiles, 1965, 1968; Shuval, 1970). Survival of enteroviruses in the marine environment has been demonstrated by a number of investigators. Enteric virus survival in estuary and ocean waters has been shown to be dependent upon temperature, biotic flora, degree of pollution, and virus type (Metcalf and Stiles, 1968). A virucidal activity in seawater has been demonstrated, but it may have only a minor role in inactivating enteric viruses in estuarine and ocean waters.

The importance of enteric viruses is not in their numbers but in their infectivity (Scarpino, 1974). One tissue-culture dose is considered to constitute an infectious dose, meaning that only a few virus particles are needed to initiate an infection in a susceptible host. Thus, it has been necessary only to show the presence of viruses in water, with less emphasis placed on quantitation. Since enteroviruses of human origin in estuarine and coastal waters may remain infectious for a significant period of time, depending on environmental factors, it has been suggested that enteroviruses themselves may serve as the most valid indicator of pollution. Poliovirus and infectious hepatitis virus (hepatitis A) have both been suggested as indicator agents. Unfortunately, the data show that virus inactivation or die-off in marine water is unpredictable. Marine water with the same salinity collected from the same site on different days may show wide variations in viral survival patterns (Atkins et al., 1974).

Thus, the major effort, at present, in research on water-borne viruses is in development of sensitive methods for recovering viruses from marine waters and for determining survival times of these viruses in different types of water (Berg, 1974; Malina and Sagik, 1974). Monitoring of estuarine and coastal waters for enteric viruses will eventually be commonplace. For the present, routine monitoring of potable water and wastewater for enteric viruses is yet to be accomplished on a large scale.

Methods available to detect viruses in water are many and varied, including gauze pads for pre-concentration *in situ*; membrane filter adsorption; electrophoresis; ultrafiltration hydroextraction; precipitation, adsorption-elution; separation with two-phase polymers; soluble ultrafilter; and ultracentrifugation (Foliguet et al., 1973; Hill et al., 1971). The main problem in virus isolation, namely, the large volumes of water that must be examined (up to 100 liters per sampling) appears to have been overcome (Hill et al., 1972; Sobsey et al., 1973). A virus concentration unit, designed by Melnick and co-workers, is being used for virus monitoring in water supplies throughout the world. At the International Conference on Viruses and Water, Mexico City, June 9–12, 1974, it was clear that adequate methods for concentrating large volumes of water for enterovirus monitoring are now available.

In general, the methodology for isolation and characterization of indicator viruses is in the developmental stage. Perfecting these techniques is the main concern of research work underway. Still unknown is how widespread viruses are in estuaries and coastal waters. Also, the incidence of viral diseases transmitted via polluted estuarine and coastal waters is not known. Some new methods for viral detection may improve and speed up virus isolation and characterization, viz., the use of Australian antigen as a marker for hepatitis B virus. Australian antigen has already been isolated from clams contaminated by untreated sewage from a coastal hospital (Mahoney et al., 1974). Other such markers may be discovered as research on the enteroviruses progresses. Survival of viruses in estuarine and coastal waters remains to be fully clarified. There is no doubt but that research to answer these questions must be done.

Alteration of the Natural Microbial Flora

An aspect of the ecology of estuarine and marine waters, about which next to nothing is known, is the alteration of the natural microbial flora induced by introduction of pollutants. That bacterial species in an estuary demonstrate seasonal cycles has been shown (Kaneko and Colwell, 1972). It is logical to assume that microorganisms associated with the biota, water, and sediment of estuaries and coastal waters are in a delicate balance.

Introduction of sewage, industrial wastes, or other pollutants will first impact upon the microflora. The microbial response is very rapid, within hours or days, at the most. A shifting of microbial species and physiological types will occur in response to the influx. Species selection will take place, as, for example, the dominance of *Aeromonas* spp. in sewage effluent. The effects of such shifts in the microbial populations are completely unknown. Yet, they may result in fish kills, clam mortalities, marsh grass diseases, and noxious odors and appearance of the receiving waters.

Microbial populations may well prove to be the "fine-tuning" mechanism of the estuarine and marine ecosystem. However, not enough research is being done to provide the necessary information. Since new methods for automating microbial data collection and processing by computer have been developed (Oliver and Colwell, 1974), such questions are no longer so overwhelmingly complex and, in fact, can be answered, if the proper research effort is provided.

Efforts of Specific Effluents on Microbial Populations

Recent work has shown that in areas receiving petroleum, pesticide, or heavy metal discharges, the microbial flora contains significant petroleum-degrading, pesticide-metabolizing, or heavy-metal-mobilizing bacteria (Walker and Colwell, 1973; Nelson and Colwell, 1974). Similarly, in estuarine and marine waters receiving sewage, pulp mill, or canning wastes, the heterotrophic bacterial populations increase significantly. The point which can be made is that these respondent bacterial species may be usefully employed as markers or indicators of such pollution. Little research effort has been directed explicitly along this line. It is suggested that such efforts may prove substantially rewarding for those concerned with chronic, low-level environmental impact, where the grosser symptoms of environmental deterioration are not seen.

Implicit in such an application is, however, that extensive and relatively complete knowledge of the natural microbial flora is available. Alas, this is not so and, again, the plea which is now nearly a cacophonic chorus, sung by botanists, zoologists, limnologists, oceanographers, and, now, microbiologists, is that baseline studies must be done. Numerous studies and countless analyses have been discarded due to the lack of the necessary baseline data. It is of great importance that the yardstick for measurement is available and that yardstick is baseline data. Unpolluted environments, as well as polluted ones, must be studied to determine the natural balance of the autochthonous microbial species, so that impacts of pollutants can be assessed.

Microbial species may act to concentrate such pollutants as heavy metals, or serve to pass polluting materials on through the food chain, especially in the case of filter or detritus feeders and protozoans (Wavre and Brinkhurst, 1971; Burke, Small, and Colwell, in press).

EVALUATION OF PRESENT STATUS AND RECENT ADVANCES

There have been improvements in the methods of isolation and characterization of the indicator organisms of human health significance, namely, *E. coli* Type I, *Salmonella*, Enterococci, Clostridia, and Enteroviruses. However, the concept of a single indicator organism as the measuring unit for the health of an estuarine or coastal ecosystem is in dispute. The indicator organisms are each subject to the vagaries of environmental and biological parameters, so that consistent results in survival studies are not always obtained. Enteroviruses appear to be the better indicators of human health hazard but the technology of virus isolation and characterization is cumbersome and complex, too much so for routine monitoring applications.

Indicator organisms for measuring the health of the ecosystem itself are not available although biological assessment of water pollution has been studied in Central Europe, comprising a saprobity system (Bick, 1963). Estuarine and marine microbial ecology, in fact, is still in its infancy, relative to molecular and medical microbiology. Understanding of the role of microorganisms in the food chain is sparse and unreliable, at best. Too few competent experiments have been done and much too little information is available on this very important aspect of the estuarine and marine ecosystem.

It is obvious that microorganisms are expected to degrade the pesticides, heavy metal compounds, petroleum, and other pollutants entering the estuaries and coastal waters. Yet, embarrassingly little is known about the mineralization of these pollutants *in situ*. It is not only the pollutants that are of great concern, but the overall processes naturally occurring in any body of water, as well as the processes that occur when any perturbing force acts on the system. Bodies of water are in constant flux. Clearly our knowledge of processes mediated by microorganisms is far too meager for appropriate management considerations. Furthermore, the realization that microorganisms may actually concentrate carcinogens in petroleum or convert relatively harmless petroleum components to carcinogens is only just now being perceived by both scientists and management.

The improved methods for coliform, enterococci, virus, Clostridia, and other microorganism isolation and characterization are directly applicable for use in the estuarine environment. The more recent work on isolation of bacteria and viruses from estuarine and coastal water provide improved methodology useful in assessing the human health hazard extant in the nation's estuaries and coastal waters.

The information now being obtained on microbial mobilization of heavy metals, pesticides, detergents, petroleum, and other pollutants in estuaries and coastal waters will permit better assessment of the capability of such ecosystems to withstand the influx of such pollutants. One result may prove to be that the scope and magnitude of pollutants now entering certain of the nation's estuaries and coastal water regions are beyond the capacity of the indigenous microbial populations to mineralize them; hence, accumulations of residues of these pollutants may be building up, especially in the sediments at these sites.

FUTURE NEEDS

1. The indicator organism concept must be revised. For indications of public health dangers, combinations of indicator organisms should be employed, viz., fecal coliforms, enterococci and Clostridia, or fecal coliforms and enteroviruses, and others. The advantages and disadvantages of each indicator organism should be determined so that they may be applied more intelligently to environmental assessment.

Additional indicator organisms must be sought which will point to ecosystem alteration. These may be sulfur bacteria, iron bacteria, *Aeromonas* spp., or physiological groups, such as mercury-mobilizing bacteria or detergent-degrading microorganisms. Clearly, a need for ecosystem indicators is developing rapidly as the demand for environmental impact assessment increases.

Further research to determine the variability of Most Probable Number (MPN) of coliforms must be done. It is critical that the variability of this count be determined, especially for given sites at short intervals, i.e., hours, so that the value of monitoring MPN on daily, weekly, or monthly bases can be properly assessed.

2. Improved methods for virus isolation and identification are needed. Also, an understanding of virus survival in estuarine and coastal waters and sediment is required. More ominous are the human carcinogenic viruses. The presence, survival, and distribution of these viruses in estuarine and coastal waters must be assessed, particularly in those areas receiving pollutants which can act as co-carcinogens.

3. The impact of pollutants on the biota of estuaries and coastal waters must be determined. Reports concerning diseases of fishes near sewer outfalls and in the New York Bight area are disturbing. The chronic effects of sewage and industrial wastes on the microflora should be examined.

4. There is a serious lack of knowledge of the microbial contributions to the estuarine and marine ecosystems. The role of bacteria and other microorganisms in mineralization and cycling of nutrients is, at best, vaguely understood. A great deal of research work in both basic and applied microbial ecology is both necessary and urgent.

5. There is a genuine need for automation in our warning system. The use of fluorescent antibody lasers or other scanning devices may provide auto-

matic warning systems. With such systems, bodies of water may be studied around the clock so that deviations from the normal will be immediately detected. At the present time such deviations must be excessively large to be detected. Also, present methods require 24 hours minimum for detection.

Research must be done on the basic problems of rates of function of microbes in natural water. Since the rates of processes will affect the environment in which indicator organisms reside, this aspect of estuarine microbiology must receive proper attention. The bulk of the literature on aquatic systems deals with detection of indicator organisms of various types. Thus, the rates of microbially catalyzed processes involved in overall fluxes within aquatic systems, with time, have not been properly assessed. Clearly, insight into the operations of natural systems, particularly rate processes, will provide the predictive capability for eutrophication, i.e., establishment of systems that are undesirable for given reasons, whether they be economic, aesthetic, or ecological. Basic research, in this case, must precede the application, simply because the basic information is lacking.

RECOMMENDATIONS FOR ESTUARINE MANAGEMENT AND MONITORING

Unfortunately, the recommendations offered are the obvious, namely, to restrict or thoroughly treat domestic and industrial wastes entering the nation's estuaries. Increased nutrient loads are resulting in alterations in the microbial flora, with dominance of nuisance or pathogenic species. Control of petroleum discharge, as one example, into the estuarine environment is mandatory, if the commercial fisheries and natural wetlands are to be preserved.

Better control of land use, particularly retention of marsh areas and wetlands, is required. The wetlands may be the "natural septic system" of the estuaries and wider oscillations in the microbial populations may occur, if the natural "buffering effect" of the wetland areas is not preserved.

Finally, better use must be made of microbial indicators. They are, indeed, the "early-warning" system of the estuarine and coastal zones. More intelligent use of microbial indicators and a wider range of indicator organisms are needed. Early or chronic environmental effects may be detectable, if the microbial indicators are employed wisely and carefully. The estuaries and coastal zones of the nation are a valuable resource. It is both appropriate and timely that we harness the microorganisms. They may well tell us more about the environment than we had imagined to be possible.

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NATIONAL ESTUARINE MONITORING PROGRAM

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ABSTRACT

About 8,000 samples of estuarine molluscs were monitored for pesticide residues in the period 1965–1972. Residue trends and typical pollution situations are briefly described. Beginning in 1972, fish were substituted for molluscs. The basic needs for a continuing monitoring program are described.

INTRODUCTION

The importance of estuaries as either temporary or permanent homes for a majority of the commercially important fish and shellfish led to numerous early studies on man-induced changes that might affect the viability of these essential ecosystems. Preeminent among early studies were efforts to define the role of persistent pesticides which could collect in or pass through estuarine systems in surface runoff from rivers to the sea.

Concern about the potential threat of such pollutants in the marine environment was heightened by the occurrence of significant kills of fish and other non-target organisms in rivers and tidal marsh areas. That such kills were primarily accidental did not decrease the possibility that less obvious but not necessarily less significant events might be taking place as a result of chronic, low levels of pesticide contamination in estuaries. It was not known to what extent such contamination might follow the use of registered synthetic chemicals for the control of plant and animal pests in the surrounding drainage basin.

To assess the significance of persistent chemical residues it has been necessary to monitor their existence, magnitude, and seasonality in the environment. These field data, however, are useful only to the extent that the effects of these chemicals on the most sensitive life stages of significant species in the estuarine community are understood. Such information must be gained under controlled laboratory conditions and, regrettably, data of this type are still mostly fragmentary.

MONITORING BIVALVE SHELLFISH

However, laboratory studies of the eastern oyster and related molluscs had progressed by 1965 to the point that estuarine molluscs could be utilized as biological tools to monitor levels of synthetic chlorinated pesticides in the field (Butler, 1967). It was recognized that residue data from field samples would not be entirely comparable to data obtained in laboratory exposure tests. Still, within certain limits, field data would indicate the kinds of pollutants present and whether the levels of contamination posed a threat to the biota or to human health.

In July 1965, the Gulf Breeze Environmental Research Laboratory, at the time part of Interior's Bureau of Commercial Fisheries, initiated a comprehensive estuarine monitoring program in cooperation with other federal and state agencies in 15 coastal states.

Laboratory studies had shown that molluscs containing moderate pesticide residues were able to eliminate them in about two weeks in the absence of continuing pesticide pollution in their environment. Consequently, the monitoring program was organized so as to sample oyster, mussel, or clam populations, depending on species availability, at 30-day intervals for a proposed 5-year period in each geographic area. Such a program could identify not only seasonal pollutional patterns but also long-term trends.

In the period 1965–72, approximately 8,000 samples were analyzed for chlorinated pesticides. The data show that high levels of pesticide residues occurred in molluscs from estuaries associated with intensive agriculture, with large volumes of municipal waste discharge, and with industrial wastes from pesticide manufacturing plants. In many areas, there was good correlation between the fluctuating levels of residues in molluscs and the seasonal agricultural use of pesticides.

The overall picture of pesticide pollution in the nation's estuaries as revealed by the monitoring data was one of widespread contamination with

DDT and its metabolites but at generally low (non-toxic) levels. In a few areas DDT residues were large enough to suggest damage to the fauna but at no time was a human health problem indicated (Butler, 1973).

DDT residues in estuarine molluscs peaked in the 1968–69 period. Since then there has been a well-defined decline in the number of positive samples and in the magnitude of residues in nearly all estuarine areas. The decrease in the number of samples with detectable residues has been as much as 66 percent in areas where adequate data are available for evaluation.

Data Utilization

Monitoring data can be of inestimable value in detecting pesticide pollution sources and in developing the background information necessary for the efficient management of estuarine systems. In this monitoring program, three characteristic pollution situations have been identified and a description of them will illustrate the general usefulness of monitoring data in establishing some of the guidelines for regulating the manufacture and registration of pesticides.

The Rio Grande River Basin on the south Texas coast is an area of intensive farming of grain, citrus, and fiber crops. The subtropical climate permits multiple harvests annually. During the mid-1960's, the recommended farm use of pesticides in this area was about five times the amounts recommended in neighboring river basins. Oysters monitored in the Laguna Madre consistently contained DDT residues about five times that of oysters from other Texas estuaries. There is good evidence that the DDT residues in the food of speckled seatrout in this area were large enough to seriously interfere with the development of the young. It seems clear, in retrospect, that the registered use of persistent pesticides on Rio Grande Basin farmlands permitted the agricultural segment of the economy to work to the detriment of the local fishing industry. The continued use of DDT would have eventually eliminated the seatrout. The demonstrated need for pest control throughout the year in this area requires the substitution of non-persistent pesticides and biological controls which will not degrade the environment.

In southwest Florida, however, the use of DDT on maturing corn and sugar cane was distinctly seasonal. The runoff from farmlands in the Caloosahatchee River Basin contained sufficient DDT during the February-April period in 1967 and 1968 so that residues in local oysters were above the suggested 'action' level of 5 ppm. There is no reason to suspect this amount of DDT would be harmful to oysters themselves, nor are oysters preyed on in nature to the extent that tissue residues of this magnitude would be detrimental to some carnivore—including man. Nonetheless, these residues would prevent the oysters being legally harvested. In this instance, the use of DDT would have increased food production on the farm and reduced it in the sea. The cure, again, is the utilization of a less persistent pesticide either alone or in combination with some biological control of the agricultural pests.

The third situation was encountered on the Georgia coast. Oysters monitored in St. Simons Sound in 1967 were found to contain toxaphene residues, a pesticide not known to have been used in the area. Levels of toxaphene in water and sediments were high enough to admit the possibility of damage to many faunal groups. By the judicious placement of trays of oysters to monitor upstream sites, increasingly large toxaphene residues were accumulated, and the source of the pollutant was identified as a component of the waste in the effluent of a pesticide manufacturing facility. In this case, identification of the source resulted in a cleanup of the contaminated river bottom by dredging and the construction of evaporation ponds for onshore disposal of the toxic effluents.

MONITORING ESTUARINE FISH

The gradual decline in pesticide residues in monitored oysters during 1970–72 pointed out the need for a pollution yardstick that would be indicative over a longer interval of time. The monthly effort in monitoring oysters no longer seemed warranted in view of the continuing absence of positive samples in many areas. Both laboratory and field data had shown that, in contrast to molluscs, persistent pesticides accumulate with time in fish tissues. Older fish in polluted waters contain progressively larger pesticide or trace element residues than do younger fish. However, body residues in individual fish fluctuate unpredictably. This may be the result of dietary stress, spawning, or some other normal metabolic process.

Since fish are readily available, a revised program was initiated in 1972 to monitor them in all of the principal estuaries of the United States and its territories. Certain criteria were established to minimize unknown fluctuations. Sample size was increased to 50 individuals. Fish are sampled during their first year prior to spawning. This narrows the time in which residues could be acquired and avoids their loss in gamete production. Both particle-feeder and carnivorous fish are monitored in each estuary to broaden the possibility of finding any pollutants present. During the first two years of the program, fish were monitored semi-annually to determine whether this was necessary or whether annual collections might be sufficiently informative.

Data Utilization

Analyses of the more than 1,500 samples of estuarine fish (37,500 individuals) monitored since July 1972 show that, in a majority of areas, DDT and other chlorinated pesticide residues have not been detectable. These data confirm the trend found in the molluscan monitoring and show that this type of estuarine pollution has indeed declined since the restriction in DDT use. The analyses show, too, that in those few estuaries where oysters were grossly polluted with DDT during the 1965–72 monitoring, yearling fish still have significantly large DDT residues. These residues, in the absence of the agricultural use of DDT, are presumably the results of recycling between the physical and biological substrates in the estuary. Or, alternatively, these residues may be the result of a continuing influx of DDT from up-river reservoirs in farm soils and river sediments.

It is apparent that the monitoring of estuarine fauna for persistent chemicals remains a continuing need. We must be in a position to gauge the effectiveness of legal restraints on the usage of known pollutants as well as be able to detect at an early date the appearance of other, perhaps still unknown, persistent chemicals that may be toxic to the biota or endanger man's food supply.

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A BRIEF ASSESSMENT OF ESTUARY MODELING— RECENT DEVELOPMENTS AND FUTURE TRENDS

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ABSTRACT

A brief, very informal, overview of estuarine modeling is presented; the great variety in estuarine environmental settings is exhibited with east and west coast examples. Typical problems confronted by the environmental scientist and engineer are discussed as well as some of the solution techniques employed to solve them.

INTRODUCTION

Estuaries are classified according to their vertical salinity and velocity profiles. For the simplest system, the profiles exhibit little vertical gradient in either parameter. More complex systems, such as fjords, can exhibit several changes in current direction in the vertical. Tidally affected rivers are also sometimes referred to as estuarine although oceanographers consider the estuary section of a river as that containing a measurable amount of salt.

There are many categories of "models." One distinction that is made here is between a *research* model, which an investigator may never document, and a *production* model, which might be implemented as a tool for management decision making (one popular catch-phrase underlying present day funding rationalizations).

Usually, no model is ever "final" since it is continually being revised as research develops. This is particularly true in estuarine systems where the dynamics of motion and dispersion of pollutants is highly complex. Added difficulties are encountered in the modeling of chemical and biological interactions. For best use, feedback between the modelers and the experimenters is required on a continuous and cooperative basis. All too often problems arise due to a lack of communication between the two groups, the modelers usually earning a reputation of the tail-wagging-the-dog.

Some would suggest that a bad model is better than no model at all since it does at least make an investigator think about the system, formalize his concepts, and make orderly what could otherwise be a chaotic field investigation. A good model will be a plus, of course, and can be the basis for the formal structure of a given estuarine research program. Suffice it to say that the field investigation designed with a sample scheme based on a "good" model has several orders of magnitude greater chance of bringing glory to its research team than to one that simply "samples."

PROGRESS IN THE LAST FIVE YEARS

Progress has been made in many aspects of estuarine simulation techniques in recent years. Theoretical development has been relatively slow except in the case of fjords, which have not been especially amenable to treatment due mostly to a lack of observational data. The so-called partially-mixed estuaries are also at an intermediate stage of development because of difficulties in treating vertical exchange processes. Theoreticians have been wrestling with this aspect for several years with little success. Indeed, many believe that a whole new theoretical approach will be required although it is difficult to envision a breakthrough which will lend itself to practical application in the near future.

In lieu of analytical solutions of differential equations, numerical solutions can be employed. The former method is used on simplified, general, representations of a given system. The simplifying assumptions employed allow investigations of many aspects of a system by, usually, rather formidable mathematical devices. When the devices aren't available or the system is too complex, then recourse to numerical methods is employed and the computer is used to carry out the relatively simple but extremely repetitive algebraic operations. There is a place for both methods; as a rule of thumb, research models are initially of the analytical variety while production models are an end product of research and employ numerical integration techniques.

Of considerably more interest to environmental scientists has been progress in analyzing chemical and biological interactions. While it is a necessity to simulate hydrodynamic processes in the best possible manner, so-called pollution problems usually are concerned with the input and effect of anthropogenic materials in the estuary or environment. If a pollutant is to be so considered then it must affect the human population either directly or through a certain chain of events. This chain may be initialized by the uptake of materials by a given organism not primarily utilized by man. Pollution, as defined by a government organization, for instance, may not be extant until several higher organisms have concentrated the substance to a detectable level—one which may or may not have deleterious effects on man. This kind of process has been known for many years, of course, but only recently have models been developed to the point of practical application, i.e., analysis or synthesis of these events.

Many of the models used today are variations of the rabbit and fox theme: a given population of rabbits is preyed upon by foxes; the fox population grows due to plentitude of food; both populations increase up to a point where the rabbits become scarce due to excessive predation. Eventually the fox population dies off due to starvation until a new equilibrium point is reached, and the cycle begins anew. Such events can be, and are, studied by mathematical models, each population being represented by a differential equation with appropriate growth and death rates, and so forth. Interaction between the two is accomplished in the mathematical treatment by coupling the equations through, e.g., a predation term. This explanation, while overly simplistic, illustrates many of the simulations of plankton growth and dieoff now analyzed through numerical experimentation. Many other reactions are also described in terms of this approach. It might be said that the easy part of the analysis is the mathematics; obtaining the right relationships, coefficients, their forms and dependencies is, and will remain, the difficult part of the problem.

SOME EXAMPLES

It will be assumed that the reader is unfamiliar with the models that have been developed for, or applied to, the systems to be described. What do these models do and, equally important, what don't they do?

East Coast

First, consider a simulation on a small (25 sq. nautical miles (n.m.)) well-mixed embayment on the east coast of the United States—Jamaica Bay, N.Y. This work was performed by Dr. J. J. Leendertse and his associates at the Rand Corporation with financial support mainly from the city of New York. As stated by Leendertse (1970) the study was "... intended as a first step toward providing a tool for a quantitative assessment of an environmental problem, i.e., the study of technical alternatives in the management of fluid waste discharges in well-mixed estuaries and coastal seas."

The work developed in stages—from representing tidal motion in the system, verification of hydraulics, simulation of dissolved oxygen and coliform concentrations, and a determination of the effect of storm water overflow on the system. The study is essentially complete; an evaluation of the benefits derived from this well-conducted effort in proportion to the costs incurred has not yet been made available. However, the project was designed to assess the effectiveness of several multi-million dollar sewage treatment schemes in the bay area. It is safe to conclude that the project costs are a minute fraction of the construction costs to be expended. A benefit/cost ratio greater than 1 can only be determined if construction cost savings were suggested by the model. It is quite possible that the model could project alternatives that would prove more costly than the initial plan costs but of more benefit to water quality. No doubt the economists have an appropriate ratio for this not unlikely event.

West Coast

As another example, a west coast study by Callaway, et al., (1969) is described. The system studied was the Columbia River from the Pacific Ocean to Bonneville Dam (146 miles, plus many islands and tributaries); rather vast and vastly different from Jamaica Bay. During low runoff periods, the lower 25 n.m. of the system are, by oceanographic definitions, estuarine. The problem here was based on a federal government decision "... to model the Columbia River system from the Canadian border to the Pacific Ocean for the purpose of evaluating existing and/or potential thermal pollution problems."

The first part of the study consisted of a description of the mathematical methods used, and the theory and documentation of the program. The second part described input and verification procedures, provided a test program, and gave examples of output. The authors end with the following admonition: "If a slide rule will do the work don't use this model or anyone else's."

As a final example, the fjord system of Puget Sound is briefly discussed. This work is presently being supported by the EPA with Dr. Donald Winters, University of Washington, as principal investigator. This study is more complex than the two just mentioned, due in part to the lack of, and difficulty in obtaining, observational data upon which to develop theory. It is more comprehensive in that it is a grant objective to demonstrate ways in which such models can be used in the numerical assessment of biological activity in fjords. To date, the project has determined several important features concerning nutrient limitation and the effect of light penetration on plankton growth (Winters, et al., 1975). In addition, it has provided hydrodynamic input (Winters, 1973) to a commercial production model of parts of the sound.

FUTURE TRENDS AND NEEDS

Most of the major needs relating to simulation models of estuarine phenomena do not concern modeling as such, but basic research on vertical diffusion processes, kinetics of sedimentation processes, air-sea interactions, rate processes of uptake by organisms, and so on. Model building is an interesting and useful occupation and proceeds at a greater rate than fundamental research on the aforementioned subjects. This is fortunate since the model can be used to guide that research, point out shortcuts, arouse suspicion of results, and suggest linkages that would not be apparent without recourse to a model which is capable of thinking in a nonlinear fashion. (Lord Rayleigh and a few other selected individuals are capable of nonlinear intuition. One can only hope that his like will continue to remain a pace ahead of the next generation of computer juggernauts.)

In summary, we seem to have gone through a period of extensive model development; in some degree progress has been in parallel with advances in computer hardware. Computerized model development, involving numerical witchcraft, has rapidly caught up with, and is capable of treating, what we know of biochemical interactions. Further progress will be at a slower rate in the future because basic research is required on all aspects of estuarine problems, including hydrodynamics.

In this day of "mission oriented" research, there is a danger in neglecting non-mission identified programs. This neglect is, of course, pitiful in the extreme when the neglecter is also a federal budgeteer.

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PORTS

FACTORS BEARING ON POLLUTION CONTROL IN U.S. PORTS LOCATED IN ESTUARINE AREAS

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ABSTRACT

Ports must meet environmental demands during a period when they are faced with abrupt changes in terminal design and operations. Attention must be given to increased costs, due to delays and confusions that will affect the economic productivity of our ports. Additional and equal attention must be placed on the effect port development will have on the existing and future ecology of our estuarine areas.

INTRODUCTION

Concern for the port environment is a recent phenomenon—10 years ago, the concern did not exist on a broad basis as it does today. Admittedly, it is still a new field in which the government and industry along with individuals are seeking ways of operating within new legislation and guidelines. Environmental concerns at the level we know them today have grown so suddenly, U.S. ports have found it necessary to make immediate adjustments to cope with them. These concerns include: legislation, federal agencies, dredging-disposal of spoils, federal permits, environmental impact statements, disposal of oily wastewater and ballast water, disposal of sanitary wastes, dilapidated piers-floating debris, land acquisition, oil spills, coastal zone management, deepwater ports, insurance demands, and vessel traffic safety systems.

Ports are also faced with abrupt changes in terminal and vessel design and operations, including increased size of petroleum and hazardous liquid carriers, super cargo ships in the container trade, bulk carriers, lash and feeder ships, tug-barge concepts, speedy hydro-foils, catamarans and surface effect ships, conversion or abandonment of finger piers, reclaiming flat lands for multi-million dollar container facilities, specialized ports, and regional port concepts. The ship operator and customer continue to demand fast turn arounds. All have environmental implications.

FUNCTION AND TRENDS OF U.S. PORTS

If we are to give proper attention to the subject, it is necessary to place in perspective the role U.S. ports play in our economy today, and the projection of "things to come." The value of U.S. port operations and their impact on our economy are shown in

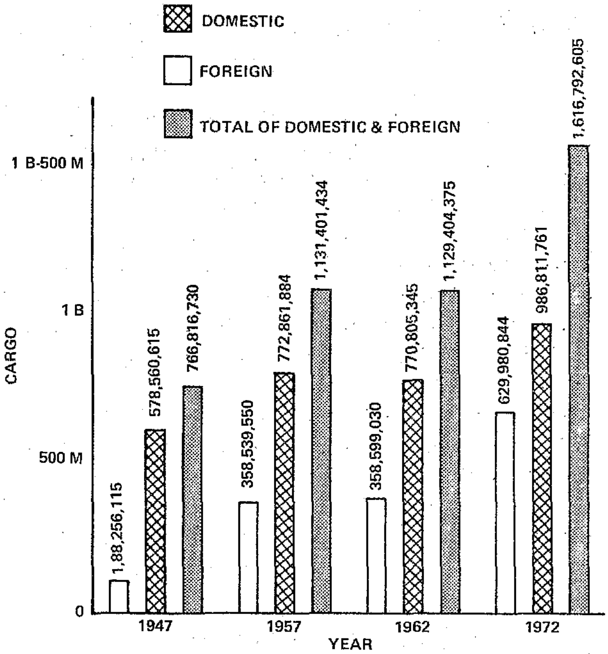

FIGURE 1.—Waterborne commerce in U.S., calendar year 1947–1972 in million of tons (2,000 lbs.).

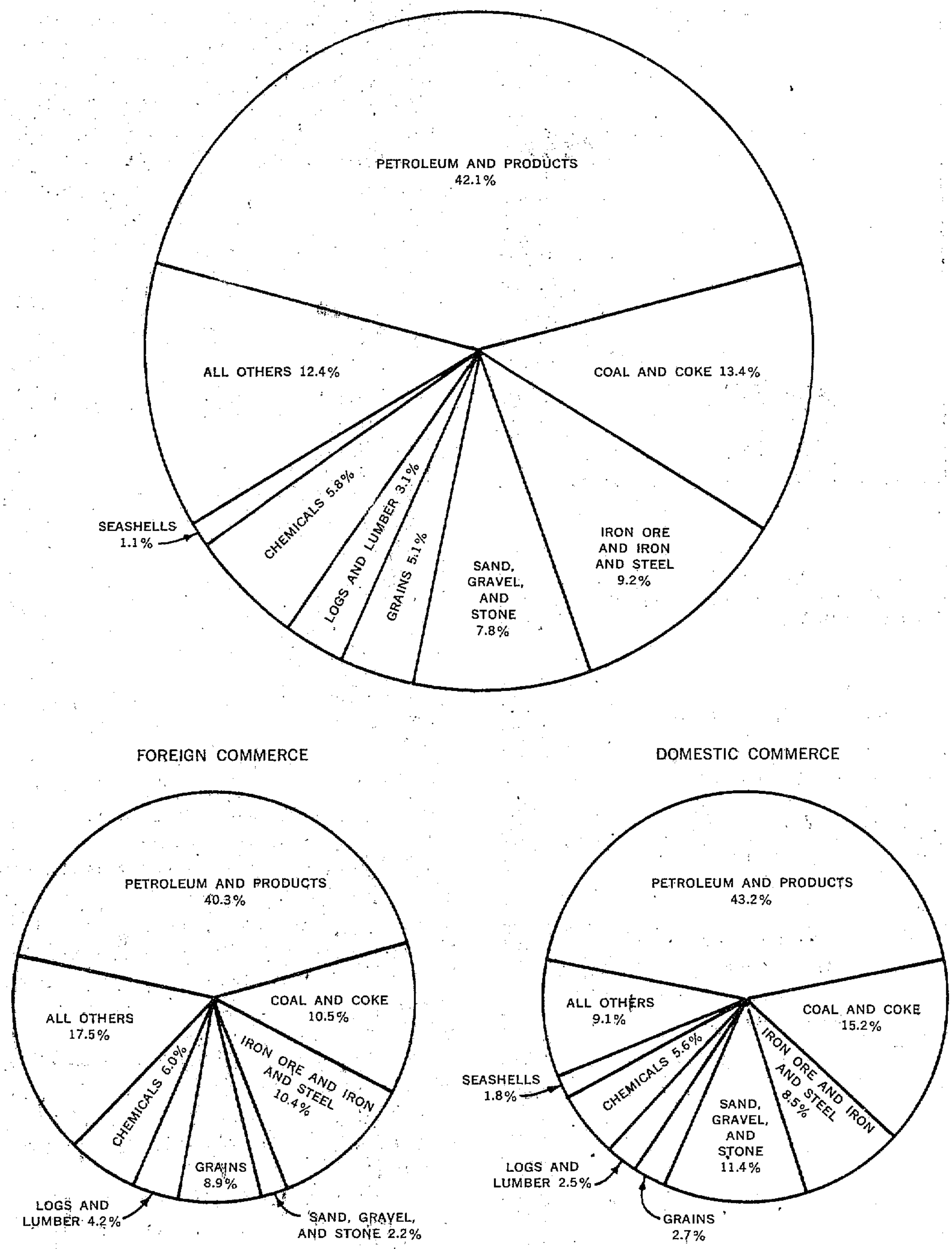

FIGURE 2.—Principal commodities carried by water-calendar year 1972 total commerce.

1972 figures, released by the U.S. Maritime Administration: "Port commerce totals over 1.6 billion tons contributing 30 billion dollars annually in direct dollar income providing livelihood for over 1.2 million people—representing over 3 billion dollars in terminal facility investments."

The growth trend in port commerce since 1947 is shown in Figure 1, and the principal commodities carried by water for calendar year 1972 are shown in Figure 2.

VESSEL TRAFFIC

Two excellent studies were recently completed, projecting future tonnage at United States ports to 2000.[1]

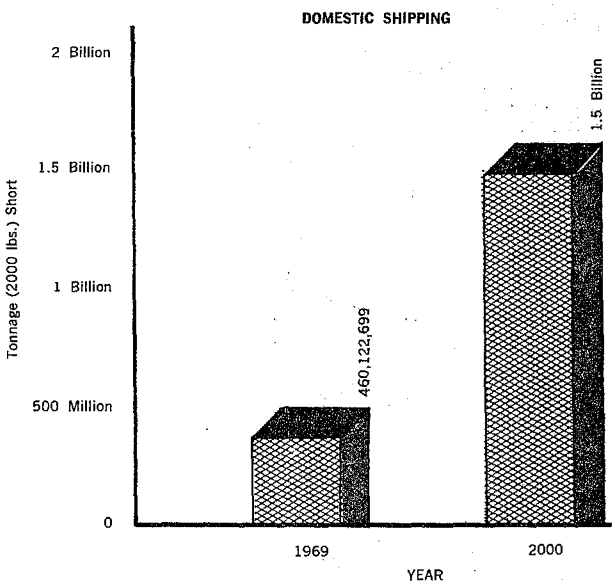

FIGURE 3.—Trends and projection of domestic ocean cargo growth, coastal and intercoastal (including Puerto Rico, Hawaii, and Alaska) 1969–2000, as projected in the Kearney Study.

Figure 3 shows significant trends in domestic ocean cargo (coastal and intercoastal, including Puerto Rico, Hawaii and Alaska), as projected in the Kearney Study.

The Litton Systems Study on the future of oceanborne shipping explores trends in the volume of oceanborne trade, from 1950–1966 with projections to 2043. See Figure 4.

The study also projects trends in growth of the world merchant fleet from 1966 to 2043, which will have an impact on vessel traffic, hence concern for the port environment (Figure 5).

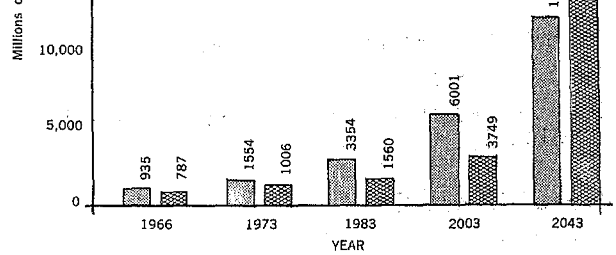

FIGURE 4.—Litton Systems, study of the projection of volume of oceanborne trade into 2043.

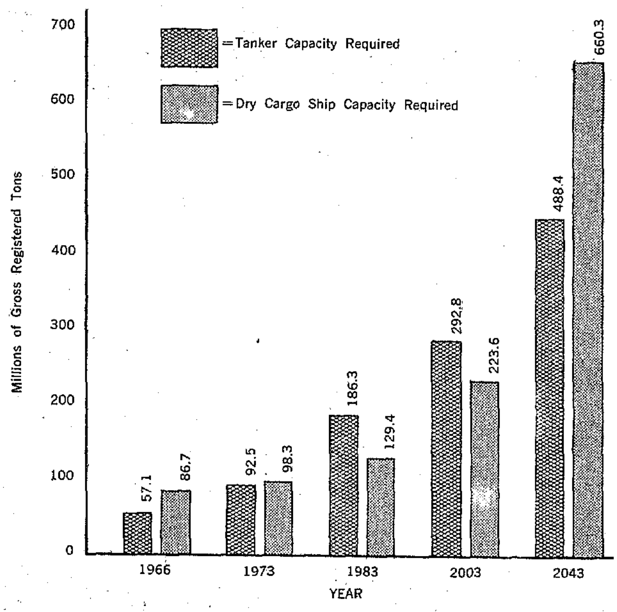

FIGURE 5.—Litton Systems Study showing forecast of growth in the world merchant fleet into 2043.

The studies show that within the next 15 years development of coastal petroleum tank barge trade will occur as a means of secondary distribution. During the past six years (1968 date of Litton Study), there has been a growing use of tank barges carrying petroleum in the coastal trade. See Figure 6.

The Coast Guard is concerned about the increased movement of petroleum and other liquids in tank barges, towed or pushed along our coastlines. They currently monitor the tank barge service to determine trends and problems.

On July 7, 1972, Congress passed P.L. 92-339, which among other issues, made it mandatory that all operators of tow boats under 300 tons be licensed by the Coast Guard (qualify for Tow Boat Operators License).

Barges carrying liquid product in the coastal trade must be inspected for seaworthiness by the Coast Guard; however, towboats under 300 tons are not required to come under Coast Guard inspection.

REGIONAL PORTS

Discussions are taking place in several port areas throughout the country, focusing on a regional port concept. Those areas include the Washington Public Ports Association, the San Francisco Bay area, and the New York ports of Buffalo, Ogdensburg, Oswego, and Albany.[2] There is some thought that the "re-

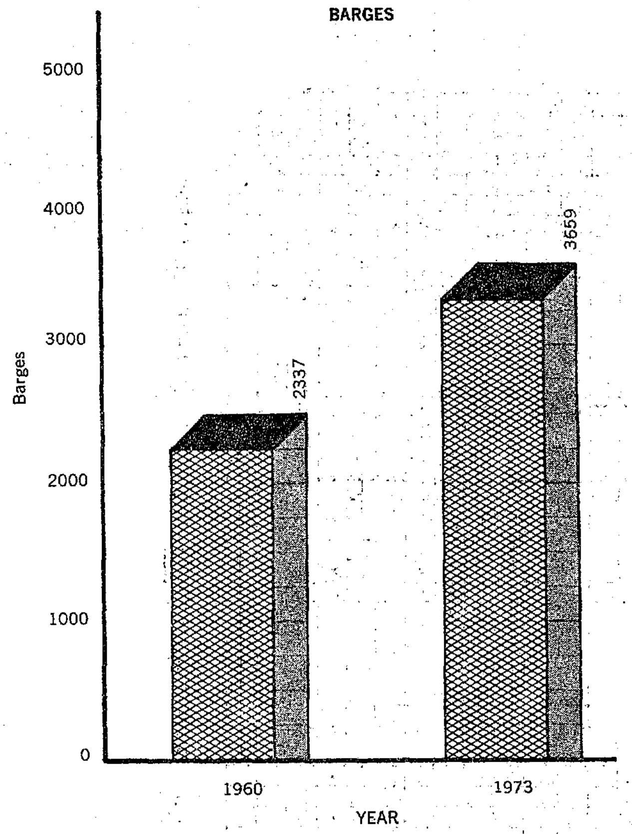

FIGURE 6.—Trend in use of tank barges (towed or pushed) in inland waters and coastal services, under Coast Guard inspection. Note: Inland waters and coastal numbers were not separated until 1973. Percentage increases for individual services will be recorded separately in the future.

gional port concept" is sponsored by the federal government and is an intrusion into the free enterprise system. However, it must be noted that studies at current port areas were initiated at the local level.

One of the principal objectives of the studies is to determine the value of a number of small ports versus a regional port to serve U.S. trade, and keep U.S. products flowing into competitive world markets. A secondary benefit would be cleaner coastal water with all commercial activity centralized at one port, rather than a number of small ports. The major pollution concern would be to mobilize funds, expertise, manpower, and equipment at one port to prevent and control possible oil spills and other pollutants from vessel traffic and port operations.

FEDERAL LEGISLATION

Some of the pertinent federal legislation influencing port environment and operations from 1969 to the present include, by title:

Refuse Act of 1889
Federal Water Pollution Control Act (FWPCA) of 1948. (As amended 152-61-65-66-70-72) P.L. 91-224 (4-3-70)
Federal Water Quality Standards Act of 1971. P.L. 92-500 (10-18-72)
Ports and Waterways Safety Act of 1972. P.L. 92-340 (7-10-72)
Marine, Protection, Research and Sanctuaries Act of 1972. (Ocean Dumping Act) P.L. 92-532 (10-23-72) (As amended 1974, P.L. 93-254)
Deepwater Ports Facilities Act of 1974.
Coastal Zone Management Act P.L. 93-583 (10-27-72)

This legislation, with resulting regulations and federal agency administration, requires constant attention and monitoring by port personnel.

FEDERAL AGENCIES INVOLVED

As new federal legislation was passed, and regulations and directives written, port directors and terminal operators found it difficult to keep informed. Communications between federal agencies and port directors were improved by a series of meetings arranged through the American Association of Port Authorities and the U.S. Maritime Administration.

Figure 7 is a matrix listing of federal agencies involved in a port environment, depicting areas of overlap in duties and responsibilities, which tend to cause confusion in the port industry. This situation is particularly reprehensible when the agencies work in consort to prepare adverse reports on a specific project, but then file separate objections as if their determinations were individually and independently reached.

It is difficult to quantify the extent of the confusion, its impact and resulting delays and costs, other than to state that it exists and attention must be given to clarifying the situation. The matrix shows there are 69 separate port environment activities involving over 50 federal agencies or bureaus. It shows over 550 different steps must be taken to process port-related activities.

DREDGING-DISPOSAL OF SPOILS

The Army Corps of Engineers, in fulfilling its mission in the development and maintenance of the navigable waters of the United States is responsible for the dredging of large volumes of sediments each year. Annual quantities approach 400 million cubic yards of dredge material for both maintenance and new work. Costs

FEDERAL AGENCIES

ACTIVITY	ARMY			COMMERCE										HEW		HUD	INTERIOR							
	COE	ACOHP	CEO	BRTA	EDA	MA	NMES	NOS	NWS	OCZM	EPA	FMC	EPC	FDA	PHS	CPAD	BLM	BOR	BSFW	NPS	BIA	BR	OCG	USGS
Permits	X										X	X			X									
Licensing				X							X		X	X										
Certification										X	X				X									
Letter of Permission or Approval	X	X					X				X					X	X	X	X	X	X	X	X	X
Coordination	X		X	X			X			X	X					X			X				X	
Review	X	X	X			X	X	X	X	X	X					X	X	X	X	X	X	X	X	X
Enforcement	X			X			X				X		X	X	X				X				X	X
Fines							X				X	X		X	X									
Environmental Impact Statement	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dredging/Filling	X	X					X			X	X						X		X					
Dredge Spoils Disposal	X	X					X			X	X						X		X					
Anchorages	X							X																
Aids to Navigation								X	X															
Harbor Protective Works	X							X	X															
Harbor Lines	X							X																
Ports & Terminal Facilities	X			X	X	X		X		X													X	
Intermodal Transportation						X																		
Vessels				X		X		X				X											X	
Port Security & Safety																								
Vessel Traffic Control																								
Locks, Dams & Canals	X						X						X						X		X			X
Bridges & Causeways	X																							
Harbor Tunnels	X																							
Pipelines	X																						X	X

ACTIVITY	LABOR	STATE			TRANS'PN							TREASURY	USDA	OTHER						
	OSHA	IBC	IJC	OMA	FAA	FHA	FRA	OPLS	SLSDC	UMTA	USCG	BOC	AP HIS	AEC	FCC	FEA	OMB	PCC	TVA	WRC
Permits												X								
Licensing					X	X	X	X		X	X			X	X					
Certification					X						X									
Letter of Permission or Approval		X	X																	
Coordination						X					X			X						X
Review				X	X	X	X	X		X	X			X			X			X
Enforcement	X				X	X	X	X			X	X	X	X	X			X	X	
Fines	X				X	X	X	X				X								
Environmental Impact Statement	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dredging/Filling																	X		X	
Dredge Spoils Disposal											X								X	
Anchorages											X									
Aids to Navigation											X								X	
Harbor Protective Works																				
Harbor Lines																				
Ports & Terminal Facilities	X				X					X	X	X							X	
Intermodal Transportation	X				X	X	X	X				X								
Vessels	X		X							X	X	X		X					X	
Port Security & Safety	X										X	X		X						
Vessel Traffic Control											X		X					X	X	
Locks, Dams & Canals		X	X															X	X	
Bridges & Causeways		X	X			X	X				X									
Harbor Tunnels																				
Pipelines		X	X					X								X				

FIGURE 7.—Federal authorization for activities in U.S. navigable waters or ocean waters relative to environmental protection.

FEDERAL AGENCIES

	ARMY			COMMERCE										HEW		HUD	INTERIOR								LABOR	STATE		TRANS'PN								TREASURY	USDA	OTHER						
ACTIVITY	COE	ACOHP	CEO	BRTA	EDA	MA	NMES	NOS	NWS	OCZM	EPA	FMC	EPC	FDA	PHS	CPAD	BLM	BOR	BSFW	NPS	BIA	BR	OCG	USGS	OSHA	IBC	IJC	OMA	FAA	FHA	FRA	OPLS	SLSDC	UMTA	USCG	BOC	AP HIS	AEC	FCC	FEA	OMB	PCC	TVA	WRC
Submarine Cables	X																																						X					
Aerial Power Lines	X							X					X																															
Recreation	X						X			X						X	X	X	X	X		X													X									
Recreational Boating								X	X									X																	X								X	
Boating Safety								X	X																										X									
Marinas and Small Boat Facilities	X				X																																							
Inland Waterways	X					X												X																	X								X	X
Great Lakes	X			X		X			X	X	X	X	X			X		X	X	X	X	X	X	X		X	X								X		X							X
St. Lawrence Seaway	X					X			X		X	X	X																				X				X							
Panama Canal & Terminals	X					X						X																														X		
Waterborne Commerce	X			X		X																						X							X								X	
Foreign Trade Zones				X		X								X	X																					X	X							
Offshore Ports & Terminals	X									X							X						X									X			X					X				
Outer Continental Shelf								X		X							X						X	X																				
Offshore Oil Drilling																																								X				
and Mineral Extraction										X							X						X	X																				
Offshore Nuclear Power Siting										X			X				X																					X		X				
Offshore Oil Leasing										X							X						X	X																X				
Energy Conservation				X									X										X	X																X			X	
Urban Development	X				X					X						X																		X										
Urban Mass Transit																X																		X										
Land Use Classification		X								X						X	X				X		X	X																				X
Flood Control	X								X							X						X		X						X													X	X
Water Supply	X				X					X			X		X	X					X	X		X																			X	X

Water Quality			X				X			X	X				X	X			X		X			X		X	X								X		X						X	X
Oil Spills			X				X			X	X								X																X									
Oily Waste			X			X	X			X	X								X																X									
Liquid Chemical Waste			X			X	X			X	X								X																X									
Other Hazardous Substances			X			X	X			X	X								X						X										X			X						
Sanitary Waste			X			X	X			X	X				X				X																X									
Solid Waste			X			X	X			X	X								X																X									
Harbor Debris Cleanup	X		X			X	X				X				X	X			X																X									
Air Pollution			X								X				X										X																			
Stack Emissions			X			X					X				X										X																			
Thermal Pollution							X			X	X		X						X																			X						
Coastal Zone Management	X					X	X			X									X				X			X	X								X									
Shoreline Erosion	X							X	X	X	X						X	X		X				X																				
Estuarine Sanctuaries							X			X									X																X									
Marine Sanctuaries							X			X									X							X	X	X							X									
Wetlands							X			X								X	X	X	X																							
Wild & Scenic Rivers							X			X								X	X	X																								
Marine Ecology			X				X			X	X								X																X									
Fish & Wildlife	X						X	X	X	X								X	X	X	X																						X	
Aesthetics		X								X						X		X		X																								
Historic Values		X								X						X				X	X																							
Climatology								X	X													X		X											X									

ACOHP — Advisory Council on Historic Preservation
AEC — Atomic Energy Commission
APHIS — Animal and Plant Health Inspection Service (USDA)
ARMY — Department of the Army
BIA — Bureau of Indian Affairs (INTERIOR)
BLM — Bureau of Land Management (INTERIOR)
BOC — Bureau of Customs (TREASURY)
BOR — Bureau of Outdoor Recreation (INTERIOR)
BR — Bureau of Reclamation (INTERIOR)
BRTA — Bureau of Resources & Trade Assistance (COMMERCE)
BSFW — Bureau of Sports, Fisheries & Wildlife (INTERIOR)
CEQ — Council on Environmental Quality (EXEC. OFC. OF PRESIDENT)
COE — Corps of Engineers (ARMY)
COMMERCE — Department of Commerce
CPAD — Community Planning & Development (HUD)
EDA — Economic Development Administration (COMMERCE)
EPA — Environmental Protection Agency
FAA — Federal Aviation Administration (DOT)
FCC — Federal Communications Commission
FDA — Federal Drug Administration (HEW)
FEA — Federal Energy Administration
FHWA — Federal Highway Administration (DOT)
FMC — Federal Maritime Commission
FPC — Federal Power Commssion
HEW — Department of Health, Education & Welfare
HUD — Department of Housing & Urban Development
IBC — International Boundary Commission (US-CAN & US-MEX)
IJC — International Joint Commission (US-CAN)
INTERIOR — Department of the Interior
LABOR — Department of Labor
MA — Maritime Administration (COMMERCE)
NMFS — National Marine Fisheries Service (NOAA-COMMERCE)
NOS — National Ocean Survey (NOAA-COMMERCE)
NPS — National Park Service (INTERIOR)
NWS — National Weather Service (NOAA-COMMERCE)
OCZM — Office of Coastal Zone Management (NOAA-COMMERCE)
OMA — Office of Maritime Affairs (STATE)
OMB — Office of Management & Budget (EXEC. OFC. OF PRESIDENT)
OCG — Office of Oil & Gas (INTERIOR)
OPLS — Office of Pipeline Safety (DOT)
OSHA — Occupational Safety & Health Administration (LABOR)
PCC — Panama Canal Company
PHS — Public Health Service (HEW)
SLSDC — St. Lawrence Seaway Development Corporation (DOT)
STATE — Department of State
TRANSPORTATION — Department of Transportation
TREASURY — Department of the Treasury (CUSTOMS)
TVA — Tennessee Valley Authority
UMTA — Urban Mass Transportation Administration (DOT)
USCG — U.S. Coast Guard (DOT)
USDA — U.S. Department of Agriculture
USGS — U.S. Geological Survey (INTERIOR)
WRC — Water Resources Council

presently (1974) exceed $150 million per year and can be expected to increase sharply, reflecting at least in part, the cost of attempting to reduce the potential for pollution of the environment.

* * * * *

The Corps presently maintains over 19,000 miles of waterways and 1,000 harbor projects. In the past, the Corps' decisions concerning open-water disposal of dredged materials have been based primarily on economic considerations. Plans for future dredging and disposal activities must now reflect proper considerations of costs and environmental constraints.

* * * * *

Due to the fact that dredging and the disposal of dredge materials occur in such highly variable environmental situations, it has been generally accepted that a universally applicable methodology cannot be satisfactorily developed. Consequently, it was concluded that a broad based program of research was required to provide definitive information on the environmental impact of dredging and dredged material disposal operations.[3]

* * * * *

The overall objective of the Dredged Material Research Program (DMRP) is to provide sufficient decision-making tools to those agencies with dredging and disposal responsibilities to enable them to choose the most environmentally compatible, technically satisfactory, and economically feasible disposal alternatives.[4] See Figure 8.

In 1973, Committee XV (Environmental Affairs) of the American Association of Port Authorities conducted a survey among its members to determine environmental port problems. Thirty-six U.S. corporate members responded. Dredging and disposal of spoils proved to be the major problem of 16 of the reporting ports.

In 1974, AAPA Committee III (Ship Channels and Harbors) conducted a National Seaport Federal Waterway Funding Survey. Of the 54 responses, 24 cited serious disposal problems causing increased costs and delays for channel construction and maintenance. "Spoils disposal problems are evidently affecting many port regions," the report indicated.

FEDERAL PERMITS

The Federal Water Pollution Control Act Amendments of 1972 established a new system of permits for discharge into the nation's waters, replacing the 1899 Refuse Act Permit Program. The federal agencies given responsibility for protecting our oceans and waterways with their permitting authority may be found in the matrix (Figure 7).

The Army Corps of Engineers retains authority to issue permits for the disposal of dredge fill material in specific disposal sites, subject to EPA veto of

Research Area	Research Task
Environmental Impact and Aspects of Open Water Disposal	A. Evaluation of Disposal Sites (1)* B. Fate of Dredged Materials (1) C. Effects of Dredging and Disposal on Water Quality (1) D. Effects of Dredging and Disposal on Aquatic Organisms (1) E. Pollution Evaluation (1)
Environmental Impacts and Aspects of Land Disposal	A. Environmental Impact Studies (1) B. Marsh Disposal Research (1) C. Containment Area Operation Research (1)
New Disposal Concepts	A. Open Water Disposal Research (2) B. Inland Disposal Research (3) C. Coastal Erosion Control Studies (3)
Productive Uses of Dredged Material	A. Artificial Habitat Creation Research (1) B. Habitat Enhancement Research (2) C. Land Improvement Research (3) D. Products Research (2)
Disposal Areas Reuse and Multiple Utilization	A. Dredged Material Drainage/Quality Improvement Research (2) B. Wildlife Habitat Program Studies (1) C. Disposal Area Reuse Research (1) D. Disposal Area Subsequent Use Research (2) E. Disposal Area Enhancement (2)
Dredged Material Treatment Techniques and Equipment	A. Dredged Material Dewatering and Related Research (2) B. Pollutant Constituent Removal Research (1) C. Turbidity Control Research (1)
Dredging/Disposal Equipment and Techniques	A. Dredge Plant Related Studies (3) B. Accessory Equipment Research (2) C. Dredged Material Transport Concept Research (4)

* Numbers in parenthesis indicate the beginning year of the research task.

FIGURE 8.—Outline of dredged material research program.

disposal sites. However, in the new Corps permitting system, no time schedule for processing permits has been developed. When objections are raised at the district level, an extensive time lapse develops while a decision is considered at a higher level.

There is no indication that the requirement to obtain permits for port projects is opposed by the port industry. However, it is important that there be no long delays in granting permits which might result in added costs to port projects, with possible adverse effect on the water quality in estuarine areas.

ENVIRONMENTAL IMPACT STATEMENTS

The EIS is now a responsibility under the National Environmental Policy Act (NEPA) of 1969—Section 102 (2) (c). The program is administered by the Council on Environmental Quality (CEQ), established under Section 202 of the NEPA.

An EIS must be filed for all projects which significantly affect the quality of the human environment and for which a major federal action, such as funding or licensing, is involved. The EIS must take into consideration the economic values of a project as well as the environmental impact. A healthy balance must be retained for the welfare of the ports and the country.

The Army Corps of Engineers has 900 environmental impact statements to write on maintenance projects alone. At the present rate, the Corps can only handle about 60 EIS a year, although, as of January 1, 1976, every Corps project will require an EIS.[5] Several ports have indicated problems resulting from the requirement to provide an EIS. It is difficult to quantify and document each problem; however, general comments express concern over agency guidelines being changed during preparation of the project and where more than one agency is involved, the conflicting guidelines used by different agencies in judging the project.

DISPOSAL OF OILY WASTE AND BALLAST WATER

Based on the President's message of May 20, 1970, directing the attention of the port industry to the problem of "Facilities for the Reception of Ships' Oily Waste and Ballast Water," the Maritime Administration (Division of Ports and Terminals) and the American Association of Port Authorities established an ad hoc committee to review, study, and propose action. The committee consisted of representatives from the U.S. Maritime Administration, Environmental Protection Agency, American Institute of Merchant Shipping, American Petroleum Institute, U.S. Coast Guard, and the American Association of Port Authorities.

As a result of this Committee's recommendation, a contract was awarded to conduct a study to:[6]

a. Determine the volumes of oil waste which would arrive at U.S. ports under various restrictions or permissible discharge.

b. Define systems for collecting and processing these volumes.

The study identifies the types of oily wastes brought into nine selected ports by commercial shipping and estimates 1970 quantities based on "no discharge" criteria, the "1969 Amendments," and the "no sheen" criteria. Quantities for 1975 and 1980 are also estimated, with the report concluding that 16.5 billion gallons of oily waste would be collected at U.S. ocean and inland ports in 1975, rising to almost 17.0 billion by 1980. If reception facilities are not available, there is no way to determine if, in fact, any of these wastes would reach estuarine areas. Ships today are prohibited from pumping bilge and ballast water in U.S. ports. If, however, the IMCO Convention specifics are not in force by 1980, ships will still be able to pump these wastes at sea.

Conceptual designs for collecting, treating, and disposing of the oily wastes, with no additional environmental degradation, range from the use of oil-water gravity separators in small volume ports, to large storage tanks adjacent to separator and/or refining capabilities in larger ports.

The suggested role of government is limited to assisting business in expanding existing capabilities through grants, loans, and research. When government-owned facilities are available, the study recommends leasing to entrepreneurs.

The problem has not at this time been defined regarding costs versus income to an entrepreneur, a port authority, or private terminal operator who must provide the necessary facilities. These would include:

a. Reception capabilities
b. Storage capabilities
c. Separation and treatment capabilities
d. Obtaining necessary permits to discharge separated water back into surface waters
e. Service charge to ship operator with possible resulting increased cost to consumer
f. Disposing of reclaimed oil, or disposing of waste oil
g. Possible delays to vessel with resulting costs

The role of the entrepreneur is not clearly defined. Refinement of regulations and policies is necessary before any large investments are made by the businessman.

Industry has entered into several programs to alleviate the problem of disposal of oily waste generated aboard ship, without direct discharge into the seas and waterways:

a. Load on top method
b. Holding tanks
c. Improved tank cleaning
d. Oil water separator
e. Segregated ballast tanker

Research by the Coast Guard and the American Institute of Merchant Shipping have not as yet established numbers or costs on these methods or total effectiveness of these programs. At this time it appears that no statistics are available. Very few American flag vessels are capable of the above. Coast Guard is making an effort to learn the impact, effectiveness, and costs of these innovative programs.

The study revealed that only two ports in the country (Burns Waterway Harbor, Ind., and Seattle, Wash.) were capable of receiving and processing bilge and tank cleaning water.

The Maritime Administration is currently involved in a project to accept, treat, and dispose of ship-generated oily waste at their recently acquired Cheatham Annex Complex in York County, Va. To date, no product has moved through the facility so no numbers are available.

The Maritime Administration also awarded a contract to determine the feasibility of "Floatable Oily Waste Treatment Systems." This study determined that it would be too expensive to use old Liberty ship hulls, placed in U.S. harbors for this project. There is also a limited supply of Liberty ships available. No further action is planned.[7]

The Maritime Administration has also commissioned studies to determine the functional capabilities and costs for volume acceptance of oil waste separation units aboard ship. If a unit can be developed to function properly aboard ship, it would help to eliminate the port problem of providing reception facilities. To date it appears no feasible shipboard unit will function properly under all conditions to handle the problem.

Ports must have an oily waste implementation program operational within 12 months after 15 nations have signed the IMCO Agreement, or by January 1, 1977.[8]

DISPOSAL OF SANITARY WASTES

It is increasingly apparent vessels will be prevented from discharging untreated sewage in U.S. territorial waters. EPA has established a "no-discharge" standard for all vessels.

The Coast Guard proposed regulations to implement EPA's standards for marine sanitation devices were published in the Federal Register on March 1, 1974. The proposed regulations govern the design, construction, testing, certification, and manufacture of marine sanitation devices. Public hearings were conducted inviting comments and suggestions. The Coast Guard is presently redrafting the regulations based on the input.[9]

More than half of the comments received were directed in whole or in part to the EPA standard. The gist of these comments was objection to the federal no-discharge requirement. In view of this general discontent with the standards, the Coast Guard has broached with EPA the question of the efficacy and appropriateness of the existing standards. Discussions between the agencies is currently underway.[9]

The Coast Guard and Navy are studying and experimenting extensively with equipment and methods of operation within their own vessels to meet EPA and state requirements and standards.

The Maritime Administration also has an extensive research and development program on the disposal problem of sanitary wastes. Using Liberty ships to accept sanitary wastes from vessels and municipalities was explored but proved too costly and ineffective.[10]

The recreational fleet, which is a significant factor in the water quality of any port must also meet standards and criteria. Marinas to service this type of vessel have introduced pump-out and reception facilities ashore, but no inventory has been taken to date and the impact is not known.

Major commercial ports in the United States have done little to provide for the reception of liquid sanitary wastes from commercial vessels of all types and sizes. The only ports with significant waste reception facilities are Burns Harbor, Ind., Toledo, Ohio; Miami, and Jacksonville, Fla.[11] It would appear that port areas will need guidance as to required hookups to receive sanitary waste at pier facilities and proper lead time to install them.

While attention is being given to the reception of sanitary wastes from vessel operation, it is important to note that port and harbor waters will not improve in quality until such time as all municipal wastes now emptying into the harbors are diverted to municipal treatment plants.

DILAPIDATED PIERS—FLOATING DEBRIS

A problem having great significance on the immediate port environment has been the deterioration of dilapidated port structures resulting, in part, in varying degrees of floating debris. In the past, a cooperative, yet not specifically defined program of federal and local effort functioned to remove dilapidated wharves and to collect and remove drift from navigable waterways.

To add additional confusion to an already misunderstood and fragmented program, involving the U.S. Army Corps of Engineers and the Coast Guard, the Federal Office of Management and Budget (OMB) in early 1973, announced its opposition to any federal subsidy for removal of drift and dilapidated piers. This decision was based on costs and OMB opinion that this is a local port problem.

Dilapidated structures and floating debris involve three major port environmental problems:

a. Visual pollution
b. Floating debris hindering the collection and disposal of spilled oil
c. Large floating logs, a danger to small boats

The Department of Transportation, through the U.S. Coast Guard, sponsored an exhaustive debris study. The types and quantities of waterborne debris found in coastal, harbor, and estuarine areas are described in the report. Regional variations of the types and quantities of debris, its sources, and the natural effects on concentration and quantity are described. Debris handling practices are discussed and equipment is identified and evaluated.[12]

Many recommendations are made including the suggestion that the Coast Guard initiate or become involved in joint debris oriented programs with the Environmental Protection Agency, the Corps of Engineers, and the Navy. It is claimed in the 460-page study that this will help to eliminate overlapping efforts by these organizations.

Inconsistencies in the debris programs find the Army Corps of Engineers financing some port debris pickup programs, while physically participating in others. Among the ports who finance their own debris pickup and patrol programs are Baltimore and Miami.

LAND ACQUISITION

In January 1975 the Environmental Affairs Committee of the American Association of Port Authorities, conducted a survey among its 80 U.S. corporate members to determine if they were experiencing any problems because of environmental legislation in acquiring the necessary land for expansion of existing port facilities. Nine ports reported problems in acquiring land for expansion and nine others reported problems in obtaining land within their existing port facilities. The survey also asked if U.S. ports were experiencing problems in obtaining permits to develop the land. The survey indicated permitting problems existed at the local, state, and federal levels.

The Port of Oakland, Calif. reported as follows:

> With regard to the portion of your questionnaire and survey dealing with land acquisition, we face problems of securing necessary approvals from as many as 31 different agencies in a typical port project. I hope in the coming year, AAPA through its various committees, will develop firm and strong recommendations as to how these problems can be met and what solution should be sought.[13]

COASTAL ZONE MANAGEMENT ACT OF 1972

Response to the above survey indicates that the 35 responding ports are aware of this Act. However, only 23 of the responding ports reported they were involved in the planning and implementation of the Act in their state, and only 23 had assigned personnel to be involved in the planning and implementation. Twenty-nine ports felt port authorities should be involved.

Thirty ports reported they had growth plans requiring expansion involving over 15,000 acres between now and 2000. It was disturbing to note, however, that only 17 ports had brought their growth plans to the attention of the coastal zone management authorities in their state.

A factor that will be of considerable importance to this program and the future of U.S. ports, is the Maritime Administration (MarAd) NOAA Memorandum of Understanding which was consummated November 20, 1973, regarding MarAd assistance in port and navigation facilities development in the coastal zone. In view of the integral role which coastal zone management plays in MarAd programs and activities, MarAd will receive from NOAA individual state and territory coastal zone management programs for review and return a written evaluation and commentary. Under this agreement, MarAd will be in a position to exercise some influential comment on pollution and pollution control at the port level. To date, MarAd has received no coastal zone management plans for review.

OIL SPILLS IN OUR PORTS AND HARBORS

This is an ever-increasing problem and one that requires considerable attention from government and industry at all levels. Oil spills from vessel and terminal operations are mostly unintentional, the cause of a miscue by manpower, or malfunction of equipment. In some instances oil is spilled intentionally by poor judgment through pumping of ballast or bilges. Regardless of the type of incident, oil is deposited in our waterways, costing millions of dollars in cleanup and ecology damages. Research and development projects through EPA, MarAd, Coast Guard, Navy and industry have resulted in improving the still primitive state of the art to attack an oil spill by controlling, removing, and disposing of it. But much remains to be done.

There is a newly formed national trade association representing the interests and serving the needs of the oil spill and hazardous substances control industry. Membership is open to all interested parties; however, members are primarily (1) third party contractors; (2) manufacturers or suppliers of equipment; (3) individuals in private or governmental capacities involved with oil and hazardous substances spill cleanup and containment operations.[14]

Objectives of the new organization are: (1) communication of the industry's practices, trends and achievements; (2) establishing liaison with governmental agencies; (3) developing industry standardizing programs; (4) assisting the industry, wherever appropriate, regarding insurance; and (5) obtaining radio frequency allocations for oil spill operations.

EPA has published regulations involving shoreside facilities, and the Coast Guard has published regulations on shipboard operations, both designed to control oil spillage. So far, both programs are lagging.[15]

EPA estimates there are more than 14,000 oil spills in U.S. harbors and waterways a year. EPA reports nearly 3 million gallons of oil were spilled in 83 cases investigated by EPA in the first quarter of 1974. EPA has introduced a new 2.6 million gallon test tank at Leonardo, N.J., in an effort to find better ways of handling the nation's "intolerable number of oil spills."[16]

ENVIRONMENTAL CONSIDERATIONS FOR DEEP WATER PORTS

The Administration has recognized the need for establishing offshore deepwater port facilities and the need for new comprehensive legislation to govern their establishment and operation.

More than 100 ports in the world are capable of handling the large supertankers, and there are over 300 tankers of 200,000 DWT, or more. This is clear evidence that consideration must be given to facilities to handle this size vessel serving our energy needs. The Port Facilities Act of 1974 was designed to give attention to this subject.

ATTITUDES IN ENVIRONMENTAL AFFAIRS

The American Association of Port Authorities, comprised of over 80 U.S. ports, recognizes the port industry's responsibility to the environment. In 1970, AAPA authorized the formation of Committee XV (Environmental Affairs), with specific duties and responsibilities.

In 1972, AAPA Directors authorized competition among U.S. ports for the "Recognition of Outstanding Environmental Programs" award to encourage additional attention to environmental responsibilities by port authorities. In 1973, 14 U.S. ports entered the competition and in 1974, 11 entered. Extensive briefs were presented to the judges, who represented EPA, Coast Guard and MarAd.

> Programs included improvement and beautification of port property through planting of grass, trees, and shrubs; painting structures; providing barrier screens; installing sewage systems; eliminating open burning; removing deteriorated piers; oil spill contingency plans; port personnel participating in community environmental programs; construction of park with lighted walkways; fountain, picnic tables, etc.; directives to reduce air pollution; encouraging businessmen in the port to improve their environmental habits; program to prevent salt water intrusion into viable estuaries; dust control program; dredging and spoil disposal programs; traffic control systems to prevent accidents; providing equipment to control pickup and dispose of spilt oil in the harbor; debris removal; establishing performance standards; 100 acre public park with bicycle park and trails; recycling program for port generated paper; bond issues to finance pollution control equipment; regulations on noise abatement; and landscape design.

Several ports are now employing personnel with full time assignments on environmental affairs. The California Association of Port Authorities has announced the appointment of a planning and environmental consultant.[17]

INSURANCE DEMANDS ON U.S. PORTS

Indications at this time are that ports are not experiencing any major financial hardships imposed by additional costs for insurance because of environmental constraints. However, a prominent Washington attorney with experience and expertise on pollution control laws and their impact on the Marine Industry, concluded his paper before a recent conference in Washington with this statement:

> The foregoing pages outline a body of law that is comprehensive, complex and constantly changing. It isn't surprising, therefore, that the traditional response of many marine industry executives has been 'Let the insurance carriers worry about the law. I need to tend to my business'. While this approach may have worked in the past, rapid growth of regulatory requirements affecting the design and operation of vessels and shoreside facilities gives rise to the inescapable conclusion that effectively accommodating to the regulatory environment is a substantial part of the "business" which needs tending to and can, in fact, mean the difference between profit and loss. When pollution abatement requirements can add nearly 25 percent to the cost of a vessel, it is clearly essential to make certain that such requirements do not discriminatorily affect your operations vis-a-vis those of your (domestic or foreign) competitors.[18]

VESSEL TRAFFIC SAFETY SYSTEMS

Coast Guard continues to expand its activities and responsibilities to improve maritime safety in harbors and waterways as it accelerates implementation of the Ports and Waterways Safety Act of 1972. Traffic safety can be the number one deterrent to vessel casualities, thereby reducing the spillage of oil in the waterways. The U.S. Coast Guard seems to have an effective program underway. Systems in San Francisco and Puget Sound are presently in operation and regulations have been drafted to require their mandatory use. Systems for other selected ports are in the planning or construction stage.

Ports and waterways have been ranked according to their need for vessel traffic systems. The list is based on an analysis of casualty statistics utilizing an algorithm developed through the VTS Issue Study. (March 1973.)

The Coast Guard programs on bridge to bridge radio-telephone communications will contribute greatly to traffic safety, and reduction of casualties.

The need for attention to the orderly control of shipping in and out of our waterways is apparent with the increased size, carrying capacity, and volume of traffic existing today and projected for the future. The following chart depicts the growth and size of petroleum carrying vessels from 1956 to present date:

Name	*Tons*	*Bbl. cap.*	*Launched*
Sinclair Petrolore	56,089	350,000	1956
Universe Leader	85,550	550,000	1957
Universe Apollo	104,520	800,000	1959
Manhattan	108,590	900,000	1962
Nissh Maru	130,250	950,000	1962
Tokyo Maru	130,250	950,000	1966
Idemitsu Maru	206,000	1,700,000	1966
Universe Ireland	326,000	2,500,000	1968

The following table prepared by the U.S. Navy shows the crash stop capabilities of tankers under full astern conditions:

17,000 ton vessel	5 minutes	1/5 of a mile
200,000 ton vessel	21 minutes	2.5 miles
400,000 ton vessel	30 minutes	4.5 miles

The stopping ability of the giant ocean carriers can be a serious problem both in open and congested waters.

TRENDS AND RECOMMENDATIONS

Three basic trends are apparent. These are indicative of the approach, attitudes, involvement, frustrations, and concern for the future of U.S. ports and the water quality in our harbors, waterways, and estuarine areas.

a. Federal, state and local legislation, guidelines, regulations, and directives will continue and will have their impact on port operations and water quality.

b. The port industry is making adjustments in policy and administration to participate in environmental programs.

c. Facilities, equipment and personnel required to respond to these environmental constraints will present a financial burden to the port industry.

Basic recommendations:

a. Recommend that immediate responsibility be given to a Special Advisory Board to evaluate and resolve confusion, delays and overlapping responsibilities from federal, state and local legislation, guidelines, regulations, and directives and their resulting environmental impact on ports. It is further recommended that this board include members of the port industry.

b. Recommend that immediate attention be given to determine the financial burdens placed on U.S. ports, through environmental constraints and how this might affect the future of U.S. ports and U.S. markets in world trade.

It is recommended that attention and support be given to H.R. 1084, a bill "To amend the Merchant Marine Act of 1920, to establish a grant program to enable public ports to comply with certain federal standards, to direct the Secretary of Commerce to undertake a comprehensive study of the present and future needs of public ports in the United States, and for other purposes."

Federal legislation on security measures, safety regulations (OSHA), and environmental constraints is bound to have a serious financial effect on U.S. ports. These issues require careful evaluation as to their effectiveness versus costs.

Review procedures that result in conflicts and communication gaps between local, district, and Washington headquarters of federal agencies involved in these projects.

The cost to purchase and develop new land for relocation of facilities and obtaining permits for dredging and spoils disposal for these projects needs to be reviewed.

RECOMMENDATION: (Federal permits)

1. Reduce number of federal agencies required to judge an environmental project. Immediate and careful attention should be given to the matrix (Figure 7), to determine its accuracy and to make recommendations that result in less confusion with resulting delays.

RECOMMENDATION: (Environmental impact statements)

1. Clarify conflicting guidelines from federal agencies for content of material for acceptance of environmental impact statements. Particular attention should be focused on requirements of Department of Interior (Fish and Wildlife) versus Department of the Army (Corps of Engineers).

2. There also appears to be an unnecessary duplication of effort in preparing an EIS. An applicant must prepare an EIS on a project, and the federal agencies with responsibility to this project must also prepare an EIS on the same project. This results in serious time delays.

3. Investigate background of projects requiring an EIS from the Corps. They are behind schedule. Recommend more manpower.

RECOMMENDATION: (Oily waste and ballast water—sanitary)

1. Entire problem needs review and refinement. Coast Guard, EPA, MarAd and AAPA must try to resolve this. Legislation calls for definite action by 1980. The industry does not appear prepared to meet that deadline. Further research and development on shipboard equipment to process the wastes are necessary.

2. The Water Resources Congress has made a recommendation worthy of consideration: "We strongly favor federal regulation and authority to pre-empt state regulations insofar as discharges from vessels in navigable waters are concerned. We also urge development of standards and standard procedures for the removal of shipboard wastes to shoreside facilities."

TRENDS: (Shipping and port industry) The following trends are apparent and require attention:

Increase in cargo movements—increased volume of ship movements—increased size of vessels—new terminal design—port to port service—requirement for new land for port development—deepwater ports—reduction in use of traditional port facilities—changes in handling bulk, liquid and general cargo (large container ships)—overcrowded waterways—increased costs for dredging and disposal of spoils—regional ports—the increased use of LNG vessels—and demand for fast turn-around of ships.

RECOMMENDATION: (Shipping and ports)

1. An overview is needed to establish basic policy changes in funding dredging projects at existing ports versus deepwater ports. The future of traditional ports versus regional ports must be examined. The effect of a large number of smaller vessels versus the supership in relation to vessel safety and avoidance of accidents requires attention.

2. Additional attention is required on the carriage of LNG and the location of port facilities to receive this cargo. Safety precautions must be examined, and further attention is required on how a port and a port community must respond to a major collision of an LNG ship with a tanker or general cargo ship in a restricted ship channel or while tied up at berth.

3. Concern should be continued on the inspection of equipment and licensing of personnel in the carriage

of petroleum products in tank barges (of all sizes) engaged in traffic along the coast.

RECOMMENDATION: (Dredging and spoil disposal)

1. Review criteria published by EPA on constraints to dispose of spoils for a more realistic approach.

2. Attention should be given to assure adequate congressional funding of the Corps dredging responsibilities. The amount of money funded by FY 1976 will not meet the needs for new project and maintenance work.

3. Determine cost to government and ports caused by delays, confusion, and misunderstanding due to conflicting guidelines and demands of state and local environmental agencies versus federal agencies.

RECOMMENDATION: (Dilapidated piers—floating debris)

1. Careful review of present study being conducted by the Corps. Particular attention is necessary to damage, with resulting costs, to bridges washed out during storms from floating debris.

RECOMMENDATION: (Land acquisition—Coastal Zone Management Act)

1. Individual ports should review their states' Coastal Zone Planning Program under the Coastal Zone Management Act to determine how it might affect land acquisition for port development.

2. Attention is also required as to why no Coastal Zone Planning Program has been presented to MarAd under the 1973 memorandum agreement between MarAd and NOAA.

3. Ports should become acquainted with the Coastal States Organization, which was formed in 1969 to provide a vehicle for the interested states to make their views known on marine and coastal programs and policies.[19]

RECOMMENDATION: (Oil spills)

1. More R & D on prevention, cleanup equipment and expertise to respond to a spill. Provide adequate depths in channels and waterways traveled by oil barges serving port areas to prevent groundings with resulting oil spills. Improved and expanded training program for Coast Guard officer assuming on scene command at oil spills. Suggest specialized designated officer classification.

2. Expansion of Coast Guard and private "oil spill" training schools. Examine current program at Texas A & M. Enlarge through government financing if necessary.

3. More attention is needed at the federal level through the office of EPA (and possibly Coast Guard) in providing local communities with criteria, guidelines, and assistance in locating disposal sites for both liquid and solid wastes collected from oil spills. This is a very critical issue, and attention to this problem is essential.

RECOMMENDATION: (Deepwater ports)

1. Before implementation of guidelines and policies, clarification is needed regarding jurisdiction, including issuing of licenses, permits, policing, regulations, construction, underwater lands, safety, pipelines, oil spill control and removal, and so forth.

2. Additional study is required on the effectiveness of a single point mooring in open deepwater ports.

3. If the deepwater (offshore) port issue is broadened beyond the reception of petroleum products, such as the reception and transfer of dry bulk cargos, considerable additional attention is required, particularly as it relates to existing land oriented port areas.

RECOMMENDATION: (Insurance demands)

1. An evaluation of this issue requires additional attention. Ports do not seem immediately affected at this time, but it is apparent that vessel insurance in handling petroleum products will have some effect on product cost.

RECOMMENDATION: (Vessel traffic control)

1. The Coast Guard has an excellent program. Funds should be continued so as not to impair its operation.

2. Avoidance of accidents is the basic deterrent to oil spills.

CONCLUSION

There are many unsolved problems that need attention. The federal government is concerned; the port industry is concerned. Both hope to solve the problems that still exist in order to improve the environmental health and welfare of our ports and estuarine areas.

REFERENCES

1. An analysis of the markets for domestic waterborne shipping by A. T. Kearney, Inc., of Chicago for MarAd. (Published Feb. 1974 at cost of $600,000.)

   Oceanborne Shipping: Demand and Technology Forecast. (Litton Systems for U.S. Dept. of Commerce. June, 1948)

2. The U.S. Maritime Administration has endorsed the intention to establish Regional Ports through the office of Marvin Pitkin.

3. Excerpts from paper given before 1974 Pollution Control in the Marine Industries, sponsored by the International Assoc. for Pollution Control in Washington, D.C., of May 14, 15 and 16 by A. J. Green, Jr., Research Sanitary Engineer, Office for Environmental Studies, U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.; and F. H. Griffis, Major, U.S. Army Corps of Engineers. Program Manager, Dredged Material Research Program, U.S. Army Engineers Waterways Experiment Station, CE, Vicksburg, Miss.

4. Section 123 (i) of Public Law 61-911 directs the Army Corps of Engineers (with EPA assistance) to undertake "A Comprehensive Program of Research, Study and Experimentation Relating to Dredge Spoil," which "shall include but not be limited to, investigations on the characteristics of dredged spoil and alternative methods of its disposal." The Corps has begun the $30,000,000 5-year study under the direction of the chairman of the eight-man advisory committee, BG, Allen Clark, Jr., USA (ret.).

5. Statement of Major General John Morris, of the Army Corps of Engineers at a convention of the Gulf Intracoastal Canal Association in February 1974.

6. Disposal of Oily Waste and Ballast Water from Vessel Operation Study contract was awarded to Frederic R. Harris Inc., in the amount of $654,000.

7. "Floatable Oily Waste Treatment Systems" Study was awarded to Lockheed Shipbuilding and Construction Company; contract amount: $399,040.

8. Statement of Ernest Bauer, chief, Division of Ports and Terminals, MarAd, at the American Association of Port Authorities Convention at San Juan, Puerto Rico, October 1974.

9. From a report dated July 2, 1974 from the desk of J. H. Costich, Comdr. U.S. Coast Guard, chief, Environmental Coordination Branch, by direction of the Commandant to Committee XV of the American Association of Port Authorities.

10. Conducted by Lockheed Shipbuilding and Construction Co. of Seattle, Wash. entitled, "The Feasibility of Using Surplus Ship Hulls for Floatable Harbor and River Waste Treatment Systems" (Published in 1973).

11. According to a survey made by Marine Engineering Log of 70 major U.S. ports and published in the June 7, 1973 issue.

12. Department of Transportation Study conducted by the Battelle Columbus Laboratories. Published March 1974, entitled "Waterborne Debris in Marine Pollution Incidents."

13. Ben E. Nutter, executive director, Port of Oakland, Oakland, Calif. (February 6, 1975).

14. Oil Spill Control Assoc. of America, 20245 West Twelve Mile Road, Suite 205, Southfield, Mich. General Counsel, Marc K. Shaye.

15. EPA published regulations involving shoreside facilities; Coast Guard published regulations on shipboard operations—designed to control oil spillage. (Both programs are lagging, according to statements of both EPA and Coast Guard).

16. EPA introduced a new 2.6 million gallon test tank at Leonardo, N.J.—better ways of handling—(Comments of John R. Quayles, Jr., deputy administrator of EPA, Oct. 2, 1974 at Leonardo, N.J.).

17. Appointment of James L. Lammie, former district engineer at San Francisco.

18. Statement of J. Gordon Arbuckle, attorney with Patton, Boggs & Blow, Washington, D.C., before the Pollution Control in the Marine Industries Conference, sponsored by the International Assoc. for Pollution Control, Washington, D.C., May 14, 15, 16, 1974.

19. Coastal States Organization was formed under the auspices of the National Governors' Conference. Chairman: A. R. Schwartz, Texas Coastal and Marine Council, Austin, Tex.

FACTORS BEARING ON POLLUTION CONTROL IN WEST COAST ESTUARINE PORTS

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ABSTRACT

The value of west coast estuarine ports is established; port operational problems attributable to pollution control are defined and analyzed. Major problem areas, including regulations and procedures, are explained with examples. It is concluded that water pollution control regulations cause the most problems and that they are characterized by unjustifiable delay, risk, uncertainty, and confusion. Remedial recommendations are given.

INTRODUCTION

West coast ports are major transportation interfaces in a worldwide commodity flow system. Whether publicly or privately owned, single or multipurpose, these ports contribute significantly to the nation as well as the regions in which they are located in terms of the availability of goods, balance of trade, and regional employment and development. In 1973, west coast ports handled 95 million tons of cargo valued in excess of $17 billion.[1] Figures on community impact of a west coast port are included in Exhibit 1 of Appendix 1.

West coast ports have generally done an exemplary job in keeping abreast of the demands of shippers and consumers. Recent changes in cargo handling concepts (containers, lighter aboard ship, roll on-roll off) have necessitated many waterfront improvements as well as the development of new facilities and the purchase of new equipment. Most World War II ships have been phased out and the new generation of ships requires wider and deeper channels, berths, and maneuvering areas. According to a Maritime Administration survey,[2] west coast ports invested over $308 million in new and renovated facilities during the period 1966 to 1972; federal investments to facilitate port operations have been many times this amount. Many ports have entered into long-term lease arrangements to amortize the heavy indebtedness incurred by the need to modernize.

Other transportation sectors have also undertaken rapid modernization of their port-related facilities to accommodate efficient and economical intermodal transportation of ocean-going cargo. Many ports now have large container freight stations where goods arriving by truck are consolidated into containers and vice-versa. New port rail yards have been developed which handle a variety of cargos, including, for example, containers on truck trailers, for distribution throughout the U.S.

Since the passage of the various clean air and water acts and the National Environmental Policy Act, west coast ports, especially those located in estuarine environments, have had to face many new problems. The regulations and regulatory procedures associated with these laws have added serious technical and financial burdens, often allowing some ports a competitive advantage over others. Frequently, the real benefits of pollution control programs, as developed by the regulatory authorities pursuant to legislative mandate, are in question; problems ensue over the use of funds on pollution control programs without adequate justification.

Embarking on any pollution control program requires time, justification, technical capability, money, effort, and specific direction. Whenever a major expenditure is required to achieve pollution control requirements, it impacts all social and economic sectors dependent on the port activity. Decisions to develop or improve related facilities may be postponed, new equipment orders are often cancelled, and lease negotiations may be tabled. In the case of west coast ports, the major problem areas appear to involve water pollution control programs, primarily due to a lack of funds, technical capability, or definitive requirements. While some air and noise quality control problems have been reported, these are apparently isolated and relatively minor compared to water pollution control problems.

Federal water pollution control programs which are creating difficulties for west coast ports include those mandated by the Federal Water Pollution Control Act Amendments of 1972 and the Ocean Dumping Act. Additional authority given to regulatory agencies by the Fish and Wildlife Act of 1958 (and the subsequent Army/Interior Memorandum of 1967) and the National Environmental Policy Act are responsible for related problems.

The implementation and administration of these Acts have significantly contributed to pollution control problems facing west coast ports. The first major pollution control program which affected west coast ports involved dredging. Experience with the regulation of this program can be characterized by the following features:

A. Uncertainty—over whether or not dredging will be permitted, future requirements, and regulatory agency activities.

B. Delays—time required to deal with and coordinate actions of all regulatory agencies involved.

C. Multiplicity of agencies involved—many single purpose agencies, often each with authority over permitting dredging and frequently called upon to review a project more than once, must approve dredging projects.

It is of serious concern to west coast ports that the above features may also affect other programs discussed under the following major problem areas.

MAJOR PROBLEM AREAS

Pollution control problems for west coast ports can be categorized in three main areas: ship operations, port operations, and port maintenance and improvement.

A. Ship operations
   1. Sewage discharge from ships while in port.
   2. Ballast or oily waste discharge from ships while in port.
   3. Accidental oil or other spills from vessels while in port.

B. Port operations
   1. Waste treatment plants
   2. Area runoff

C. Port maintenance and development. (This area involves both the improvement and replacement of landside facilities and the new and maintenance dredging of navigation channels and berths.)
   1. Status of applicable regulations and procedures.
   2. Multiple agency involvement and delays associated with permit processing.
   3. Technical feasibility of, justification for, and costs associated with applicable pollution control programs.
   4. Testing and monitoring requirements.

EVALUATION AND DISCUSSION OF FACTORS

A. Ship Operations

1. Discharge of sewage from ships in port directly into the surrounding waters is prohibited by a number of agencies. Most ship sanitary facilities are fitted to discharge directly overboard; very few have holding tanks, treatment plants, or collecting manifolds that would allow sanitary wastes to be pumped to shoreside treatment plants while in port. One solution is to disallow the use of shipboard facilities and use only shoreside toilets; another is to use portable self-contained units placed on board while a ship is in port. Neither solution is fully acceptable to either ship operators or ports since they both involve extra expense and inconvenience. Impact on shipping not otherwise normally susceptible to U.S. regulations (e.g. foreign operators) must be considered in determining the degree and acceptability of such requirements. Adverse effects on ocean shipping services—en toto largely provided by other than U.S. carriers—must be viewed in terms of world trade, balance-of-payments, and competitiveness.

Many local pollution control agencies, such as California's Regional Water Quality Control Boards, in order to comply with Environmental Protection Agency requirements, adopted blanket policies of prohibiting discharges from ships[2] apparently without adequately investigating available alternatives, the magnitude of the ship discharge problem, or the costs involved. Further, in several areas, ports are required to police such prohibitions and can be held responsible for deliberate or accidental discharges. In implementing this policy, the California board has a commitment to install dockside sewers before approving any application to the Corps of Engineers for a permit involving the construction or maintenance of a wharf or pier facility.

2. Ballast and oily wastes must frequently be discharged from ships before taking on new cargo and for trimming purposes. Such discharges, like the discharge of sewage, are prohibited in port. Some ships clean at sea while others make special trips to cleaning facilities. With regard to trim ballast, vessels must often depart from port in unstable condition until they are far enough at sea to discharge excess ballast or wastes.

Most municipal sewage treatment systems cannot handle the materials and volumes involved even if their lines are connected to port areas. The only generally available landside solution is to pump ballast and oily wastes into tank trucks or rail cars for transport to special treatment or refining facilities. This solution is very expensive, time consuming, and infrequently available.

3. Accidental spills of oil or other deleterious substances into port waters are always a possibility. The U.S. Coast Guard has developed stringent regulations covering the transfer of such materials; these have significantly reduced the probability of spills. The only reasonably reliable, available method of preventing spills from causing damage in port appears to be through the use of floating curtains to control and facilitate spill cleanup. These curtains are deployed around the vessel on docking and float above and below the water level while transfer operations occur. The question has arisen in many ports over who should purchase and operate these curtains.

B. Port Operations

1. Ship wastes, if pumped ashore, must be treated before they are returned to port waters. In most cases, pipelines, pumping stations and pre-treatment facilities would have to be installed to convey the wastes to municipal plants if they could accept them. Many municipal sewage treatment districts in which ports are located cannot accept the volumes and types of wastes which ships must discharge.

The most likely solution will probably involve construction of dual pipeline collection systems from each berth to separate sanitary and industrial treatment plants. Final distribution could be either through existing municipal systems, if they can accept the wastes, or through new pipeline outfall networks.

2. Storm water overland runoff is believed to be a major contributor to water pollution.[4] Port areas generate large amounts of direct runoff due to the magnitude of their land coverage. Port runoff problems are aggravated by their proximity to navigable waters and the fact that they are necessarily low lying areas often subject to overflow from upland tributary runoff.

Surface runoff from ports may traverse areas of many port-related activities including railyards and truck depots, scrap salvage operations, open storage, and ship repair facilities. Pollution control agencies are increasingly alert to controlling non-point source discharges. If it becomes necessary to treat port area runoff, all storm sewers as well as surface runoff will have to be intercepted and conveyed to a treatment plant prior to discharge in port waters. Understandably, many west coast port officials are concerned over the costs involved with constructing and operating such a system.

C. Port Maintenance and Development

Ports, like other industries, must modernize and take advantage of new technology and changing trends to provide efficient service and to remain competitive. The waterfront environment is unusually harsh and port maintenance must be performed on a continuing basis. Unlike most industries, however, the costs associated with port modernization and maintenance are very high compared to either port facility investment or return.

Investments from which accrued benefits are of a common, long range and often intangible nature and which promote general prosperity but are beyond the capability of private enterprise are frequently undertaken by the government. In the case of ports, such benefits, in the form of marine commerce and international trade, are recognized, and the government invests large sums in port modernization and maintenance. This is common for ports worldwide.[5] Since many pollution control measures would fall into the above category, it would appear reasonable to assume that the government should participate in underwriting expenditures associated with port pollution control.

Having the government as a partner is absolutely essential to west coast estuarine port maintenance and development; however, the partnership has many disadvantages. Federal funding programs to deepen and widen navigation channels, for instance, take an average of 17 years to accomplish. During such long time spans, technology, pollution control programs, and regulations change, and consequently the costs and usefulness of such projects.

The following specific problem areas indicate factors limiting and controlling west coast port development and maintenance from the standpoint of pollution control:

1. The status and applicability of pollution control regulations is often confusing. Most industrial point source discharges have been covered by standards issued by the Environmental Protection Agency under the Water Pollution Control Act Amendments of 1972, P.L. 92–500. Compliance with the National Pollution Discharges Elimination System (NPDES) permit program of P.L. 92–500, while expensive, has at least clarified many point source issues and focused attention on others. Ports are the terminus for many pipelines of which the origins and contents are

often unknown; yet, under the NPDES program, ports are required to apply for and procure permits or curtail discharges from all but storm drain pipelines.

Pollution control regulations, while often promulgated and enforced by federal agencies, are frequently interpreted and enforced in more stringent forms by state and local agencies. In the case of dredged material disposal regulations, the overlapping jurisdictions of both regulatory agencies and federal laws combined with failure of EPA to develop guidelines required by Section 403 (c) has caused great confusion. This situation was described by a member of the California State Water Resources Control Board as "A deplorable lack of coordination between agencies which often results in long delays which are unfair to applicants (for dredging permits) and work a hardship on the agencies involved."[6]

The greatest concern expressed by west coast ports regarding pollution control involves dredging. The status of dredging-related regulations is especially confusing since they are mandated by both the Ocean Dumping Act, P.L. 92–532, and by P.L. 92–500. Dredge disposal criteria for ocean disposal have been promulgated pursuant to P.L. 92–532, but not for inland water disposal as required by P.L. 92–500. This situation has left estuarine ports without any clear-cut regulations. In response to this dilemma, Region IX EPA issued its interpretation of the P.L. 92–532 ocean disposal criteria, modified to meet local requirements, and, as an interim measure, has extended these criteria (with some additional modifications) to cover inland water disposal. To further complicate the situation, only one of the seven California State Regional Water Quality Control Boards adopted these criteria, with modifications of their own; the other six boards reportedly use various criteria. This situation frequently results in more stringent requirements for some ports and consequently in higher dredging costs for those ports. Region IX EPA stated that final dredging criteria would be issued over a year ago. Many projects and agencies have awaited these criteria, promised on a monthly basis; a draft was released in late October 1974.

2. Prior to undertaking port development or maintenance projects, ports must procure permits from many regulatory agencies, most of which administer pollution control programs. Primarily because many pollution control regulations appear relatively nebulous and because most pollution control agencies are under-staffed to efficiently handle permits, obtaining permits is usually arduous.

Again, dredging causes the majority of problems. Both for maintenance and development purposes, dredging permits are sought more frequently by more ports than any other permit. All too frequently, a port spends months going through this process to get permits to accomplish annual maintenance dredging; often contracts must be held up or delayed because the status of or an impending decision regarding a permit is unknown. Many development projects have been deferred or cancelled during the permitting process because of uncertainties, delays, and escalating costs. A participant in a recent dredging conference described the situation: "It seems like we are on a merry-go-round—improper guidelines, rigidly applied, result in virtually impossible project requirements."[7]

3. The technical feasibility of complying with many pollution control regulations, their justification in terms of environmental benefits, and the costs of compliance in economic and social terms are very important issues to west coast ports. The most serious of these issues surrounds dredging, which provides the "lifelines" of ship navigation channels to ports.

There have been many commentaries on the adequacy, impact, and effectiveness of pollution control regulations involving dredging. With respect to the basis for the regulations, a board of consultants to the U.S. Army Corps of Engineers stated that "A correctional campaign based on inadequate evidence may be self defeating."[8] There are many arguments which indicate this may characterize the pollution control program for dredging.

First, the impact of dredging activity on water quality relative to natural resuspension of sediments appears to be small. For example, Dr. Ray Krone, a sediment expert from the University of California, has shown that in San Francisco Bay, the amount of material resuspended into the water column by estuarine wind and waves is many times greater than that due to dredging.[9] With regard to toxic metals, on which major pollution control efforts are expended, it is believed that the major cause of their presence in the water column is urban runoff.[10] Given the urban and industrial activity common to estuaries along the west coast, it is highly probable that the impact of dredging on water quality is relatively very minor. As an overview on this matter, Dr. Krone observes that "The . . . (EPA) . . . appears to feel compelled to establish guidelines for dredged spoil disposal even in the absence of information showing that publishing such guidelines will lead to improvement of water quality. In view of the large sums of money that observation of the proposed guidelines will require, and that otherwise could be spent in preventing the admission of waste discharges into the waters to prevent accumulation of toxic materials on all sediments, such guidelines should be prepared with sound knowledge of the effects of disposal on the estuary or stream. As the proposed guidelines show repeatedly, even cursory knowledge is lacking."[11]

Second, no studies have conclusively shown significant deleterious impacts on water quality caused by routine maintenance or well planned new dredging. Dredging, which approximates natural resuspension of sediments, does not add materials to the water column. While no significant changes have occurred in dredging practices in San Francisco Bay in the last 50 years (except that the amounts have increased), the local Water Quality Control Board reports that bay water quality is improving.

Third, the costs associated with compliance with dredging related pollution control regulations are high. In the San Francisco Bay, for example, the normal practice for dredging within the central bay is to dispose of the material at a deep aquatic site just off Alcatraz Island; the regulations prescribe disposal for "polluted" material at some 30 miles offshore in the ocean or on land. The cost for disposing in the prescribed ocean site is approximately three times that of disposing at the Alcatraz site. Without adequate justification, ports are very reluctant to commit such large additional expenditures. An estimate of additional costs due to dredging regulations as applied in San Francisco Bay has been developed and is included in Appendix I, as Exhibit 2.

Since ports are often bound by lease agreements, additional expenses for disposing of dredged materials are usually unbudgeted or unknown amounts which must come from other accounts if available at all. In one instance, funds which had been made available for public fishing piers and parks had to be used instead to cover the added costs of compliance. While the recreational benefits of the public fishing facilities are known, no one can identify significant benefits of complying with the dredging regulations.

Another factor aggravating the added cost situation is that many single purpose agencies with pollution control authority can and do exercise a de facto veto power over the conduct of dredging projects. A recent statement by a representative of the U.S. Bureau of Sports Fisheries and Wildlife illustrates the limited perspective that results in controls on ports; with regard to the necessity and merits of port dredging projects, the representative stated that "Although the proposed EPA criteria state that the selection of disposal sites will be based on considerations of the need for disposal, economic costs involved, available alternatives, and the extent of environmental impact, the Bureau will continue to evaluate dredging projects only from the standpoint of the impact on fish and wildlife resources. Decisions of the Bureau will not be swayed by economic considerations."[12] The Bureau has pointed out that it is their obligation to review dredging projects and to try and serve as advocates for sound biological planning.

It is not apparent that pollution control regulatory agencies are able to adequately identify any significant deleterious impacts which begin to compare with the lost benefits of foregone dredging projects or the added costs associated with compliance with the regulations. The agencies have been queried regarding the impacts of the regulations on numerous occasions with unsatisfactory results. To one query from a Congressman, for example, who asked the EPA "What specific beneficial effects will be achieved as a result of implementing the (dredging) guidelines?" EPA responded: "We believe the (guidelines) will provide a better tool to evaluate dredged spoil disposal in San Francisco Bay waters than was formerly available through the use of national (EPA) guidelines. Accordingly, the resulting evaluations should adequately protect the environment while avoiding the imposition of unreasonable burdens on navigation interests."[13] With regard to this particular response there is significant disagreement over whether or not the regulations have been shown to adequately protect the environment and whether or not they impose unreasonable burdens on navigation interests.

4. Testing and monitoring programs are required as conditions of dredging permits issued by government regulatory agencies. The costs of these programs is high, averaging from approximately 7 percent to 20 percent of the cost of the dredging. Much data has been produced from these mandatory programs but its usefulness in protecting the environment is highly questionable. Three questions regarding program usefulness have never been satisfactorily answered: (a) what is the relationship between constituents tested and water quality: (b) what is the relationship between the limits placed on the constituents (which define whether or not dredging is allowed) and water quality: (c) do the prescribed methods of analysis yield results which are indicative of actual deleterious impacts on water quality?

After reviewing the pollution control regulations and testing and monitoring procedures which are prescribed for dredging, Dr. Ray Krone observed that "The levels (limits) of constituents are arbitrarily set without justification or support of any kind. The real difficulty, from the standpoint of their use for management of dredged spoil disposal, however, arises because of the analytical (testing) methods required. . . The methods of analysis described appear to determine gross constituents or indexes of possible pollutants, rather than actual deleterious materials released to the environment."[14]

APPARENT NEEDS

The factors discussed above limit and control west coast estuarine port operation, often to a serious extent. Ports can and do play a vital role in pollution control efforts. The following points express needed reforms in the pollution control efforts as applied to west coast ports:

1. Pollution control regulations and testing procedures must be adequately based and justifiable with regard to results. Their entire impact, including that on the environment as well as on the economy and ports in particular must be evaluated prior to implementation. Also, before any regulations are implemented, agencies administering them should be fully aware of costs and of feasible alternatives available to meet regulation requirements. To this end, agencies proposing regulations or testing procedures should be required to develop both environmental and economic impact statements and to hold public hearings prior to promulgation of the regulations. This view has been endorsed by both the board of directors and the general membership of the California Marine Affairs and Navigation Conference.[15] Sound, complete, reasonable, and workable pollution control regulations can only be developed after social, economic, and environmental impacts and priorities are established, evaluated, and their relationships thoroughly understood.
2. Pollution control regulations must be applied uniformly; specific directions for their use must be supplied to all agencies at federal, state, and local levels which might use them.
3. Pollution control regulatory agencies must be adequately funded and staffed to develop fair, efficient and economical permit and review procedures for the administration of pollution control programs.
4. When pollution control measures are judged to be in the general interest, funds should be made available by the government to implement such measures. West coast ports, already financially burdened through many recent modernization efforts, provide many major contributions to the general interest. Some funding is apparently authorized in the amount of $15 million to remove in-place toxicants from navigable waterways according to Section 115 of P.L. 92–500; to date, however, west coast EPA representatives do not know how these funds can be made available.

CONCLUSIONS

In order for west coast estuarine ports to participate as fully as possible in pollution control programs, uncertainty, delays, and confusion now associated with such programs must be minimized. The perplexing problems which characterize the pollution control program for dredging hopefully can be reduced or eliminated from future programs involving other fields of port activity. A mechanism for the sharing of costs associated with port pollution control programs should be developed and implemented. In addition, a streamlined decisionmaking process for the issuance of port maintenance and development permits should be instituted, allowing full and rapid consideration of the value of port activity.

APPENDIX I

(Referenced to Text Superscripts)

1. From U.S. Department of Commerce figures compiled by the Maritime Administration.
2. U.S. Department of Commerce, Maritime Administration, North American Port Development Expenditure Survey, March 1974.
3. California Regional Water Quality Control Board, San Francisco Bay Region, Interim Water Quality Manage- Plan, April 1971.
4. San Francisco Bay Regional Water Quality Control Board, Memorandum from Executive Director on proposed shellfish policy, August 1974.
5. U.S. Army Corps of Engineers, Institute for Water Resources, Foreign Deep Water Port Developments, December 1971.
6. California Marine Affairs and Navigation Conference, Summary Proceedings: Ecology, Economics and Dredging—A Balancing Point for Navigation, October 1973.
7. Same as #6.
8. U.S. Army Corps of Engineers, Waterways Experiment Station, Disposal of Dredged Spoil (Technical Report H-72-8) November 1972.
9. Dr. Ray B. Krone, Paper to San Francisco Bay Regional Water Quality Control Board, March 20, 1974.
10. Same as #4.
11. Dr. Ray B. Krone, Paper Evaluating EPA Draft Dredge Disposal Criteria, November 8, 1972.
12. Same as #6.
13. Letter from Paul DeFalco, Jr., Regional Administrator, EPA Region IX, to Congressman Robert L. Leggett, November 30, 1973.
14. Same as #9.
15. Resolution adopted by the California Marine Affairs and Navigation Conference, October 1973.

Exhibit 1

Economic Impact of Port of Seattle*

	Number of Jobs	Gross Annual Payroll	Sales and/or Revenues
Transportation and Transportation Services			
Water Transportation:			
Steamship companies—personnel afloat	678	$ 8,401,000	$130,000,000
Tug & barge companies—personnel afloat	1,047	9,785,000	48,000,000
Pilotage and berthing services	35	457,000	900,000
Ship chandlers and other vessel suppliers	254	2,401,000	5,692,000
Commercial fishing	675	6,525,000	15,000,000
Repair and construction of commercial vessels	1,527	12,988,000	24,027,000
Subtotal: Water Transportation	4,216	$ 40,557,000	$223,619,000
Surface Transportation:			
Rail	967	$ 9,008,000	$ 18,437,000
Truck	457	4,993,000	13,137,000
Air	10	100,000	500,000
Subtotal: Surface Transportation	1,434	$ 14,101,000	$ 32,074,000
Transportation Services			
Marine construction	189	$ 1,563,000	$ 4,747,000
Physical handling of maritime cargoes (longshore and stevedoring, crating, stuffing & unstuffing of containers, local drayage, and warehousing)	2,585	24,486,000	45,763,000
Administrative activities—private (personnel ashore of steamship and tug & barge companies, freight forwarders, customs house brokers, foreign trade departments of banks, insurance companies, and trade associations)	1,704	14,445,000	8,233,000
Administrative activities—public (Port of Seattle Commission, federal, state, & local agencies, foreign consulates and trade missions)	2,111	20,512,000	47,120,000
Other waterfront related activities (marine surveyors, admiralty lawyers, consultants, maritime labor unions, and news media)	242	3,808,000	4,393,000
Subtotal: Transportation Services	6,831	$ 64,814,000	$110,256,000
Total: Transportation and Transportation Services	12,481	$119,472,000	$365,949,000
Manufacturing			
Food/kindred products	1,400	$ 10,629,000	$ 78,279,000
Wood/paper products	1,689	11,848,000	42,040,000
Metal products	464	3,748,000	13,072,000
Machinery & equipment	2,921	24,715,000	82,483,000
Other manufacturing	2,125	16,865,000	77,546,000
Total: Manufacturing	8,599	$ 67,805,000	$293,420,000
Wholesale Trades	4,320	$ 40,324,000	$ 95,154,000
Grand Total Direct Impact	25,400	$227,601,000	$754,523,000

* From Seattle Maritime Commerce and its Impact on the Economy of King County, Seattle Port Commission, 1971.

Exhibit 2

Estimated Additional Costs for San Francisco Bay Dredging Projects as a Result of Application of E.P.A. Dredge Disposal Criteria*
January 1, 1972 to October 1, 1973

Dredging Applicant	Project Size (Cubic Yards)	Disposal Site Requested	Disposal Site Approved	Estimated Additional Cost
1. Humble Oil	10,000	Carquinez Strait	Alcatraz	$ 9,600
2. USN Hunters Point	170,000	Hunters Point	Deep Ocean	77,000
3. WPRR Oakland	6,000	Alcatraz	Deep Ocean	18,000
4. Bethlehem Shipyard	125,000	Hunters Point	Deep Ocean	220,000
(one project)	25,000	Hunters Point	Alcatraz	9,000
5. Port of Oakland	95,000	Alcatraz	Deep Ocean	113,000
6. Exxon Benicia	80,000	Carquinez Strait	Alcatraz	76,800
7. Schnitzer Oakland	36,000	Alcatraz	Deep Ocean	68,400
8. Corps Oak IHC	900,000	Alcatraz	Deep Ocean	1,440,000
9. Dumbarton Br.	121,000	South Bay	Alcatraz	138,000
10. PG & E Oleum	12,000	Carquinez Strait	Alcatraz	12,000
11. Port of Richmond	10,000	Alcatraz	Land	?
12. San Leandro Mrna	350,000	Hunters Point	Land	?
				$2,181,800

* From Newsletter #6, California Marine Affairs and Navigation Conference, Oct. 30, 1973.

THE PUBLIC'S ROLE

SEA GRANT ESTUARINE STUDIES

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ABSTRACT

Approximately 20 percent of funds dispensed under the National Sea Grant College and Program Act of 1966 (PL 89-688) has been directly related to estuarine studies. Since 1971 $13 million in federal funds, matched by $8 million in non-federal support, has been directed to this area. In the same period 533 projects in support of ecosystems research, coastal zone management, pollution studies, environmental modeling, and applied oceanography were conducted under the Sea Grant Program.

Brief case histories of estuarine related studies in Narragansett Bay, Long Island Sound, the Neuse and Albemarle River Basins, Apalachicola and Escambia Bays, Barataria Bay, Matagorda Bay, and Puget Sound are presented as examples of Sea Grant work.

The applied nature of Sea Grant studies is emphasized by examples of the utilization of Sea Grant estuarine-related research. Particular attention is given to how these studies have been used by local, state, and federal decisionmaking bodies.

A partial bibliography citing 58 Sea Grant reports on estuarine research is presented.

INTRODUCTION

Incubators for much of life in the sea, estuaries are fragile environments, taking sustenance from land and sea in an unending cycle.

Influenced by both land and sea, the nation's estuaries are vital resources of the coastal margins. And the delicate balance of these nursery grounds is further complicated by man's increasing pressure on the coastal zones of this country.

An intricate network of natural phenomena and manmade intrusions converge in America's coastal zones. Each of these has a direct bearing on the estuarine environment. Research to learn more about estuaries encompasses a much broader scope than the estuary itself. One must understand the nature of adjacent bays, the islands which bar the sea from the land, shipping lanes which criss-cross the nearshore environment, freshwater inflows which feed the sea, the biological mysteries underlying the ocean's food chain, the effects of man's use of the nearby land and ocean, and the physical, chemical, and biological parameters of the nearby ocean.

Created to "achieve gainful use of marine resources" through the establishment of sea grant colleges, the National Sea Grant Program has focused a significant effort toward understanding the forces which influence the nation's estuaries. Through a partnership arrangement between the federal government and the nation's colleges and universities, the Sea Grant Program, administered by the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce, has directed more than $21 million in federal funds toward marine environmental research since 1971. In 1974, 165 projects were underway along all U.S. coasts and the Great Lakes.

Sea Grant: How It Works

When the Congress created the Sea Grant Program in 1966 (PL 89–688), it was envisioned as a marine resource effort which would be patterned, in part, after the successful land grant program fostered by the Morrill Act of 1862. Whereas the land grant program concerned itself with food production from the land, Sea Grant is concerned not only with food production from the ocean but also with the development and use of other resources—minerals, recreation, transportation, and others—which relate to the sea. To accomplish its mission, by law Sea Grant must carry on work in applied research, education, and advisory services.

Administered by the National Science Foundation from 1966 until the creation of NOAA in 1970, the program is a matching fund arrangement. As much as two-thirds of the funds for Sea Grant programs in universities and colleges come from the federal government with at least one-third coming from

Table 1.—Sea Grant Program Support by Category of Effort FY71-74

Category	1971 SG $ (MF $)	1972 SG $ (MF $)	1973 SG $ (MF $)	1974 SG $ (MF $)	Total SG $ (MF $)
EDUCATION/TRAINING	1,860,350 (1,937,878)	1,957,700 (1,469,975)	1,483,194 (2,125,273)	1,217,128 (1,869,726)	6,518,372 (7,402,952)
ADVISORY SERVICES	1,096,359 (591,344)	2,184,135 (1,158,523)	2,658,562 (1,389,705)	3,568,695 (1,791,681)	9,507,751 (4,931,253)
RESEARCH					
• Marine Technology Research & Development	1,820,889 (925,890)	3,159,949 (1,794,834)	3,037,103 (1,626,595)	2,941,518 (1,851,898)	10,959,459 (6,199,217)
• Marine Environmental Research	2,652,990 (1,708,638)	3,135,814 (1,707,906)	4,030,467 (2,411,610)	3,384,116 (2,344,411)	13,203,387 (8,172,565)
• Socio-Economics & Legal Research	524,531 (228,905)	845,176 (440,173)	1,115,015 (533,816)	909,659 (624,113)	3,394,381 (1,827,007)
• Marine Resources Development	3,685,288 (2,322,529)	3,665,132 (2,144,644)	4,532,119 (2,813,753)	5,018,347 (3,046,353)	16,900,886 (10,327,279)
PROGRAM MGM'T	904,843 (753,463)	1,390,273 (1,010,114)	1,619,758 (1,052,076)	1,721,477 (1,358,018)	5,636,351 (4,173,671)
TOTALS SG $ (MF $)	12,545,250 (8,468,647)	16,338,179 (9,726,169)	18,476,218* (11,952,828)	18,760,940** (12,886,200)	66,120,587 (43,033,844)

*Does not include $857,900 awarded as amendments to grants originating in FY72.
**Does not include $293,000 for 7 awards not requiring matching funds.

institutional sources. This matching requirement has created a partnership between government and institutions which is the cornerstone of the Sea Grant concept.

Since 1971, the program has granted $66 million to universities and others. An additional $43 million has been matched by grantees as shown in Table 1.

Support to institutions from the National Sea Grant Program takes several forms: project support for a single activity; coherent area support for several projects centered around one primary problem; institutional support for programs undertaking work in several research areas and in education and advisory service areas; special designation as Sea Grant College for universities exhibiting excellence and commitment while receiving institutional support.

Sea Grant's intent is to bring many types of expertise into marine-related work. Grantees include scientists, engineers, teachers, lawyers, economists, businessmen, and industrialists. In FY1974 3,796 individuals were involved in Sea Grant supported projects—2,334 full-time equivalents as shown in Table 2.

In 1975 eight Sea Grant Colleges had been named—Oregon State University (1971), Texas A&M University (1971), University of Rhode Island (1971), University of Washington (1971), University of Wisconsin (1972), University of Hawaii (1972), University of California (1973), State University of New York/Cornell (1975).

The Partnership

Since the program is operated to serve state and regional needs, the mechanisms for bringing university resources to bear upon these area problems and needs necessarily include local involvement. A typical university Sea Grant program, for instance, will have several advisory councils or committees helping define the most important problems for study.

Through marine advisory service field agents who live and work in the communities bordering the coast, local problems are identified. These field agents work closely with fishermen, businessmen, port directors, and others who are dependent upon the sea for a living. Through field agents, problems are brought back to the institution. Often information already exists which can help. In other instances,

Table 2.—Individuals involved in Sea Grant Projects FY 1974

Type	Research	Advisory Services	Education	Total
Faculty/Professional	1,140	325	297	1,752
Graduate Students	562	26	105	696
Undergraduate Students	274	30	101	442
Technicians	307	25	49	355
Clerical	232	80	50	374
Other	99	119	30	177
Total	2,614	605	632	3,796
FTE's	1,742	365	176	2,334

research efforts must be mounted to acquire information needed to make decisions. As information is generated it is fed back to the local areas through meetings, workshops, publications, films, or one-to-one teaching sessions.

Problems may range from the demand for trained personnel to the need for organized workshops on new state or federal regulations. But all are evaluated by local groups and university personnel to arrive at decisions about how solutions may be generated.

Where research, education, or advisory services projects are called for, proposals are written, and evaluated for scientific and technical quality by experienced professionals from the universities, state or federal agencies, private laboratories or industry. Even before the institution submits its comprehensive proposal for federal support, the project has been subjected to many kinds of reviews and judged on its relevance to local problems.

Once the NOAA Office of Sea Grants is asked to support a project, other technical reviews are made, plus a further review is made to determine its appropriateness to the Sea Grant mission. A National Sea Grant advisory panel, composed of knowledgeable individuals from industry and universities, participates in this review process and decides on grants to be made. This panel, with personnel from the Office of Sea Grants, must take into consideration not only the technical quality of the proposal but also the total funding available to the National Sea Grant Program.

Through this process of review and evaluation, projects eventually undertaken as part of the Sea Grant Program are assured of having high technical and scientific quality and relevance to the needs of the local community or state.

MARINE ENVIRONMENTAL QUALITY

Concern for environmental quality and estuarine research is a manifestation of how the Sea Grant partnership works. Sea Grant's chief concern is people, people who work in the sea, live near its shore, or benefit from its bountiful resources, and one of the important concerns of people is the quality of the environment. Sea Grant advisory field agents, working closely with local groups, help identify problems which affect the quality of the coastal and nearshore environment. Local support for Sea Grant projects often shows up as matching dollars for the project. As evidence of the local acceptance of the program, the mandatory matching requirement has exceeded the demand. Forty-one percent of the total Sea Grant funding for the current fiscal year is from matching money.

Table 3.—Numbers of projects by categories FY1971-1974

Category	Numbers of Projects (Total)			
	*1971	1972	1973	1974
RESEARCH AND STUDIES IN DIRECT SUPPORT OF COASTAL MGM'T DECISIONS	(21)	(38)	(58)	(67)
•CZM Social Sciences		13	22	32
•CZM Natural Sciences		25	36	35
ECOSYSTEMS RESEARCH	(13)	(11)	(28)	(25)
•Ecosystems Research		11	28	25
POLLUTION STUDIES	(17)	(46)	(45)	(40)
•Oil Spills		5	3	3
•Pesticides		8	6	5
•Thermal and Radioactive		11	5	6
•Metals		9	5	4
•Other		13	26	22
ENVIRONMENTAL MODELS	(15)	(20)	(23)	(25)
•Physical Processes		9	10	12
•Biological Processes		6	6	8
•Other		5	7	5
APPLIED OCEANOGRAPHY	(16)	(9)	(9)	(8)
•Chemical		2	1	1
•Physical		7	8	7
TOTAL	82	123	163	165

*Project information for FY1971 is available only by major areas of emphasis.

Although there is no specific research category labelled "Estuarine Studies," Sea Grant recognizes the importance of support to all aspects of the nearshore marine environment. Because of the many forces which impact upon the nation's estuaries, studies in several categories are considered vital to understanding the complex estuarine environment.

Work in support of marine environmental quality is carried out in five major areas of emphasis under Sea Grant: Research in Support of Coastal Zone Management Decisions; Ecosystems Research; Pollution Studies; Environmental Models; and Applied Oceanography.[1]

These major topics are further broken down into sub-topics as indicated in Table 3. Work in the coastal zone is clearly the most important area of investigation with 67 projects underway in the 1974 fiscal year. Pollution studies including oil spills, pesticides, thermal, radioactive, and metal pollution, rank second.

For the period FY1971–1974, \$13 million in federal funds and \$8 million in matching funds have been devoted to marine environmental quality studies. This area of research has received significantly more non-federal support than matching funds required by law. Characteristic of the entire

[1] Under the Sea Grant legislation, the Great Lakes are considered "salty" and studies undertaken in these important waters are included in the tables presented here.

Table 4.—Sea Grant Supported Marine Environmental Research FY1971–1974

Major Emphasis	1971 SG $ (MF $)	1972 SG $ (MF $)	1973 SG $ (MF $)	1974 SG $ (MF $)	Total SG $ (MF $)
Research in support of coastal management decisions	944,947 (742,149)	964,963 (503,835)	1,410,543 (1,037,797)	1,204,180 (1,075,194)	4,524,633 (3,358,975)
Ecosystems Research	599,500 (431,230)	379,984 (275,329)	812,677 (447,061)	563,479 (344,819)	2,355,640 (1,498,439)
Pollution Studies	420,184 (211,910)	1,059,569 (634,723)	810,215 (573,172)	686,184 (426,644)	2,976,152 (1,846,449)
Environmental Models	348,697 (178,677)	533,748 (248,250)	587,683 (200,742)	686,826 (382,208)	2,156,954 (1,009,877)
Applied Oceanography	339,662 (144,672)	197,550 (45,769)	409,349 (152,838)	243,447 (115,546)	1,190,008 (458,825)
TOTAL SG $ (MF $)	2,652,990 (1,708,638)	3,135,814 (1,707,906)	4,030,467 (2,411,610)	3,384,116 (2,344,411)	13,203,387 (8,172,565)
% of all Sea Grants	21.1	19.0	21.8	18.0	

Sea Grant program, this overmatch is evidence of the importance of working closely with local groups to identify problems.

In addition to the research volume as indicated in Table 4, much of the work of marine field agents is directed toward environmental quality. In the period FY1971–FY1974, a total of $14.4 million has been used to build a national network of marine agents. Of this amount, $4.9 million has come from non-federal sources. The strength of this network lies in its ability to work at the local level, to tap the expertise of Sea Grant institutions, and to relate research to the coastal and marine problems of the nation.

Although 165 projects in support of estuarine quality were conducted in FY1974, only a few examples are cited in this report. They are included as indicators of the kinds of local-federal arrangements which Sea Grant endorses and supports.

ESTUARINE RELATED STUDIES

New England

Narragansett Bay.—Sea Grant researchers at the University of Rhode Island are using computers to simulate various processes in Narragansett Bay.

- Ocean engineers have completed a physical model of tides and currents that has been used to predict water quality in the upper bay after a storm sewer overload and the movement of oil slicks from spills in the lower bay.
- Resource economists have developed an economic-ecological model that can be used to predict the effect of economic growth on water pollution.
- Marine biologists are devising a model that will characterize such features as animal and plant populations.

Together, the studies will lead to a coordinated model to show the interaction among the physical, biological, and economic aspects of man's use of the bay.

The physical model of the bay is based on laws of fluid motion and takes into account the effects of tides, storms, and the earth's rotation. It can predict water movement in the entire bay or at any one of 320 separate points.

It has been used to compute temperature profiles for the heated water discharge of a proposed nuclear power plant. The profiles indicate to what extent bay water would be affected by the effluent and provide clues to its potential effect on marine life.

Again using the physical model, Sea Grant scientists have been able to predict the dispersion of past oil spills, knowing only their size and location, with significant accuracy. Such predictions can help officials anticipate where a spill might spread and can be used to evaluate the effectiveness of oil spill contingency plans.

The resource economists' model of the bay can be used to predict increased pollution from new economic activity. The calculations consider wastes which result directly from increased production as well as those generated by supporting industries.

In addition to research that examines the bay as a whole, other URI Sea Grant work on the environmental impact of marinas in small inlets has led to recommendations that new marinas be located where tides or currents flush the area frequently.

In the first major study of a New England salt marsh in about a decade, Sea Grant scientists have completed an intensive ecological study of a small salt marsh embayment on the west side of Narragansett Bay.

Measurements of major populations, their metabolism, and seasonal patterns of the total salt marsh metabolism were made to ascertain energy flow within the embayment. The scientists simulated additions of sewage and heated effluent water to the salt marsh inlet. They concluded that sewage from a housing development around the marsh would lead to total depletion of dissolved oxygen in the marsh waters and that the introduction of heated water, such as power plant effluent, would cause small, but measurable lowerings of dissolved oxygen.

Long Island Sound—Using a mathematical model in New York, researchers with the State University of New York (at Stony Brook) are testing management schemes for improving water quality in Long Island Sound. One idea being evaluated could lead to better flushing of the western end of the sound and New York Harbor. It calls for building gates, or locks, across the upper East River, a major source of pollutants in the once-productive sound.

At ebb tide in the East River, the gates would be open to allow unhindered flow of clean sound water through the river, down into New York Harbor, and out into the New York Bight. Six hours later, at slack water, the locks would be closed, blocking the flow of polluted harbor and river waters back into the sound. After another six hours, the gates would be reopened to repeat the cycle.

Tests of the tidal flushing scheme with the model indicate that sewage concentrations would drop 78 percent in the western end of the sound and 50 percent in New York Harbor. The predictions assume that half the East River sewage now enters the sound.

South Atlantic

Neuse and Albermarle River Estuaries.—Sprawling between North Carolina's mainland and its Outer Banks are 2.6 million acres of sounds and estuaries, an area which ranks near the top of the state's list of most valuable resources. The North Carolina Sea Grant program conducts research aimed at contributing to the state's ability to make sound policies concerning the estuarine environment.

Scientists at the University of North Carolina are tracing nutrients—nitrogen and phosphorus as they travel into and through the estuaries to determine the effects these nutrients have on the resource. Computers are used to map changes in the estuarine waters throughout the Neuse and Albermale River estuaries. These maps also show changes in the estuaries over time.

The research has provided evidence that oxygen concentrations often drop in the summer, as algae blooms thrive and salt water settles to the bottom. Fish begin to migrate out of large areas where oxygen is low, leading scientists to believe more nutrients in the estuaries could lead to longer periods of low oxygen. Such periods could be harmful to fish and organisms that cannot leave the waters.

State agencies that must monitor and control water quality are using the information derived from these studies to gauge the impact of upstream sources of sewage and nutrients on the estuaries. Already Sea Grant researchers have recommended maximum temperature standards for industrial effluents to officials formulating water quality policy.

University of North Carolina teams also are undertaking work to learn more about the soils in the estuarine environs and the processes which shape the state's shoreline. The state's barrier islands and the rest of its coastline are threatened by erosive forces of ocean waves and currents.

Meanwhile, another research team is using Hatteras Beachgrass, a variety developed by NCSU soil scientists several years ago, to stabilize dunes. Advantages of the Hatteras grass include its hardiness. Where only five percent of American beachgrass test plantings survived the first year, the survival rate for Hatteras jumped to 70 percent.

In a related activity, the soil scientists joined with the Corps of Engineers in a project to stabilize the soil which is dredged from rivers and channels. They have found that it is possible to build productive marshlands from the dredging spoils in some areas.

In field studies and with the computer, University of North Carolina Sea Grant scientists have traced water flow through the state's tidal inlets and sounds. Field research focused on water circulation in the Oregon Inlet and Croatan-Roanoke Sound areas and in the Neuse River estuary. Using the computer, NCSU civil engineers modeled water quality, surface-elevation, and water movements in Pamlico Sound under various conditions including hurricane winds. A water quality model of the Neuse River estuary has been verified with field data. Information gained in both the field and computer studies is useful in predicting water flow and water quality and can provide valuable information for resource management decisions.

Gulf Coast

Apalachicola and Escambia Bays.—Apalachicola Bay and its drainage system are important concerns to nearby coastal counties. Franklin County, for example, is economically dependent upon the finfish and shellfish resources of the bay, which produces over 80 percent of Florida's oyster crop. Researchers from the State University System of Florida, studying the possible effects of the agricultural chemical Mirex, provided data from their Sea Grant work to the state's Department of Natural Resources Endangered Land Task Force, to the EPA, and to the Florida House of Representatives.

The team was asked to expand the scope of the project on Mirex, a chemical used to control fire ants, to include the productivity and water quality in the bay's drainage system. Funding came from the Franklin County Board of Commissioners and the Florida Department of Pollution Control.

Based on data from the Sea Grant research project in Apalachicola Bay, the State of Florida is purchasing 17,000 acres of land at a price of $4.2 million.

Data collected in Apalachicola Bay will be compared with information derived from another study in Escambia Bay which has gained national attention in recent years due to a series of devastating fishkills symptomatic of deteriorated water quality.

As part of an interagency task force established by an EPA conference in 1972, Sea Grant is involved in efforts to reverse the bay's deterioration and guide the recovery process. Data from the project has already been used in planning for a projected 30 percent population increase for the Pensacola metropolitan area over the next 15 years.

The importance of studying interrelationships between and among bays has been documented in the project. Under certain conditions, for instance, Pensacola Bay bottom water moves into the East and Escambia Bays. Knowledge of this movement is important in predicting movement of sludge out of Escambia Bay and in determining sites for waste outfalls. The study has already provided data to state officials in the development of a wastewater management plan for the drainage basin.

The data has also been used in evaluating an oil-drilling permit request and by real estate interests in coastal development.

Barataria Bay.—Initiation of Louisiana's Sea Grant program in 1968 gave Louisiana State University scientists their first opportunity to mount a major multidisciplinary study of the state's fragile and fertile coastal marshes—seven million acres of estuaries and wetlands.

In early 1969 field activities began on the Barataria Bay Project, named for a major bay-marsh complex in southeastern Lousiana. Wild Life and Fisheries Commission personnel describe the area as the most biologically productive estuary in a region acknowledged as the major nursery ground for commercial fisheries in the northern Gulf of Mexico.

Initial studies were made at widely dispersed locations to assess factors that varied spatially, such as salinity and vegetative types, as well as those that changed with tidal stage and season. The investigation has since been extended to the littoral zone from the Mississippi River mouth to the offshore area of the Barataria Bay system and to various marsh types and swamps. The results showed that the marshes and swamps play the key role in organic production necessary for nutrient generation in situ and in sediments in Barataria Bay system. Nutrients to the Barataria from the Mississippi River are limited to high flooding stage of the river in early spring, but the river flooding inundates the entire nearshore zone of the Louisiana coast with vast amounts of organic matter and inorganic nutrients annually from winter to late spring. Under investigation is the influence of the Mississippi flooding on the chemical parameters of water and sediment in the major oyster producing area east of the river, in relation to oyster growth, quality, and condition for parasite infection.

Perspectives gained from the first several field seasons led investigators to formulate a detailed plan for study, synthesis, and operational research of the total estuarine ecosystem. They have already characterized estuarine productivity by means of a detailed model and energy flow data.

This synthesis of nutritive processes will provide a scheme by which the relative importance of every consumer species in the marsh, as well as the marsh plants themselves, can be assessed in terms of utilization of commercially important shrimp and fish. Further, through estimates of plant material flushed into open waters, the contribution from coastal marshes to offshore food chains can be examined. From this information, economic questions concerned with alternate uses of the estuarine marsh and its living resources can be examined rationally.

Knowledge gained from the project has already been used to evaluate the impact of man's activities—primarily oil production related—and will later lead to recommendations for management practices in Louisiana's coastal region.

Matagorda Bay.—An example of the comprehensive approach Sea Grant researchers take toward estuarine studies is Texas A&M University's four-part resource evaluation of the Matagorda Bay area.

The study was undertaken to complement work done for the General Land Office of Texas by the Texas Bureau of Economic Geology. It is part of a continuing quest for information upon which to base coastal policy decisions.

Texas A&M's study, supported by the General Land Office and industry, involved an interdisciplinary team of geologists, biologists, oceanographers, and economists.

The team focused on water circulation patterns and their effect on coastline change and pollution dispersal; on chlorinated hydrocarbon levels in bay sediments; on the validity of interpreting environmental factors from the presence of skeletal remains of certain marine organisms; and on the economic structure of the bay area and the probable economic effects on changes in population, resources and transportation.

Pacific Northwest

Puget Sound.—In Washington, Sea Grant has supported several projects to provide impartial data for policy makers who must make coastal zone management decisions while beset by intense pressures from competing interests.

One effort by an interdisciplinary team of University of Washington economists, oceanographers, political scientists, and public affairs specialists, is a series of case studies of public controversies over potential uses of Puget Sound shorelines. The result is a major reference work on management of a large estuarine-inland waterway system.

Concern over discharge of sewage sludge from Seattle into Puget Sound led Sea Grant scientists to construct a mathematical model that describes the effects of environmental factors upon phytoplankton growth in the sound. With support from EPA, a quantitative description of the main features of mid-channel circulation in the central basin of the sound was developed. The results were used to calculate algal population dynamics and to identify and describe environmental factors which control algal growth.

The Washington Sea Grant Program has a major publishing venture underway to present, in readily accessible and useable formats, data on the marine environment of Puget Sound collected over the past 40 years. Produced with support from the Washington Department of Ecology, the materials are believed to be of great value to regional resource planners.

State and local management agencies are responding to recent EPA requirements for water quality in Puget Sound. Estimates by some Washington groups place the cost of basic data accumulation at more than $4 million. The Seattle metropolitan area (Metro-Seattle) has committed $1.1 million in local funds for studies on waste disposal. Baseline studies will be funded by the state.

TRENDS AND IMPLICATIONS

Since local and state governments hold key managerial roles in the nation's coastal zones, including responsibilities for estuarine areas, the tie to these governmental units is the Sea Grant Program's greatest strength.

As indicated in Tables 3 and 4 of this report, research and studies in direct support of coastal management decisions have grown steadily since 1971. With the passage of the Coastal Zone Management Act of 1972, state agencies and Sea Grant institutions have devoted even greater time and effort toward these important land and water areas. Not only has the federal Sea Grant support for coastal management decisions increased in the past two fiscal years (Table 4), but matching funds have amounted to approximately 43 percent of the total spent, making a cumulative expenditure of $7.8 million since 1971.

Pollution control and ecosystems research, on the other hand, has declined during the same period. Sea Grant Program directors at several universities see this as a continuing trend. They reason that pollution studies for example, have been designated as part of the EPA mission and with federal appropriations for Sea Grant programs growing slowly, the funds available must be directed to problem areas where other federal agencies have not been given responsibilities for granting and contracting.

With the creation of guidelines for state support under the Office of Coastal Zone Management, NOAA, states are beginning to plan ways to implement the coastal management law. With federal guidelines clearly asking for state management programs, the Sea Grant funded work which has already been done in many of the coastal states is proving invaluable, cementing the university-state-federal partnership.

In Rhode Island, for example, one of the first states to pass comprehensive coastal management legislation, the University of Rhode Island's Coastal Resources Center has been designated as the research arm of the Coastal Resources Management Council. The first fact-finding mission of the Center resulted in recommendations for the use of the state's barrier beaches. Based on research supported by Sea Grant, the Center made recommendations on construction and vehicle traffic which provided the basis for state beach regulations.

In other states, too, Sea Grant programs have developed supporting data upon which state agencies can begin to develop management plans. At the University of Michigan, a valuable review of state coastal management programs was prepared early in 1972, even before the federal coastal zone act was passed. Summaries of state coastal management programs were examined, including estuarine and wetlands preservation measures. The comprehensive examination of selected state programs became a valuable information source for states seeking coastal zone legislation.

In 1970, the Oregon State University Sea Grant Program prepared and distributed thousands of copies of a report entitled "Crisis in Oregon Estuaries" which reviewed the value and vulnerability of these natural resources. Fourteen major estuaries were discussed with special emphasis given to their present and potential contributions to the state's economy and the threats posed to the economy by misuse and poor management practices. The State of Oregon shortly passed coastal zone legislation encompassing all areas west of the coastal mountain range. Sea Grant also helped prepare the impact statement which led to the designation of the South Slough of Coos Bay as the nation's first (and only, at this writing) National Estuarine Sanctuary.

Stimulus for Public Decisions

Proper management of natural resources involves understanding all the ramifications of any given move—as in a game of chess. And the University of Michigan Sea Grant Program tackles resource management problems exactly that way. In fact they developed a game so stimulating that it is used by regional planning commissions and other state and local officials to help them see the consequences of decisions they make in coastal and water resource planning.

Called WALRUS (Water and Land Resource Utilization Simulation), the game was developed to provide a means of communication and interaction among the Sea Grant scientists and the public that they seek to serve. Played with four or five teams of about five members each, the players represent different economic and geographical interests. As the game progresses they learn that no matter what decisions they make, the environment is going to reflect them—for good or for bad.

All along the Sea Grant network, scientists and research managers are seeking closer interaction with state agencies and public officials. The purpose: to bring well-developed information into the decision making arena. A survey of Sea Grant programs reveals many examples of the results of such relationships:

- In New York, findings of seven Sea Grant projects assessing the state's power plant siting practices have been presented to the State Department of Environmental Conservation, the Public Service Commission, the Governor's Office and the Legislature. The information is being used in testimony at both state and federal hearings.
- In a report for the California Coastal Zone Commission entitled "Governing California's Coast," the University of California Sea Grant Program has analyzed alternative mechanisms for carrying out the state's coastal zone management plan. The Commission's policy on water quality and pesticides is based on work by Sea Grant researchers at the University of Southern California.
- In Florida, Sea Grant supported work in the University of Miami's Ocean and Coastal Law Program has contributed to passage of legislation designating Biscayne Bay as the state's first marine preserve area and to the Florida Coastal Mapping Act, the first of its kind in the nation.
- The Louisiana Coastal Zone Statute, pending before the state's legislature, was drafted for the Louisiana Advisory Commission on Coastal and Marine Resources with Sea Grant support.
- The Senate Report "Papers on National Land Use Policy Issues," incorporated information developed by the MIT Sea Grant Program.
- University of Rhode Island Sea Grant researchers have been involved in formulation of state marine sand and gravel regulations, a barrier beach plan, and in the preparation of other information needed by legislators.
- In Texas, for instance, a series of small workshops in 1970 eventually led to the state's first major conference on marine and coastal resources—one called by the governor of the state. Out of the meeting came recommendations for state action which have since led to the creation of a Coastal and Marine Council and several legislative committees. Later, Texas A&M Sea Grant work on deepwater terminals had a direct influence on the creation of a state Offshore Terminal Commission. Work now underway on the Gulf Intracoastal Waterway has been instrumental in developing public hearings on the use of the waterway.

In a number of states Sea Grantees serve on commissions or councils responsible for policy making in marine and estuarine matters. States having such arrangements include Texas, Oregon, Massachusetts, Louisiana, Rhode Island, Washington, and Hawaii. In other instances Sea Grantees hold appointments on national marine councils and are active in committees of the National Academy of Sciences and Engineering.

Sea Grant's presence is also felt in local communities through a number of other channels—workshops for teachers, 4-H meetings, civic club lectures, television and radio programs, films, bulletins, newsletters and special publications, atlases, maps, meetings and conferences. Through its research, education, and advisory service components in more than 50 colleges, universities, and other institutions, Sea Grant hopes to bring about a greater public awareness of the importance of marine and estuarine resources.

Coordination with Other Agencies

Interaction with other federal agencies is achieved through strenuous review process for all Sea Grant supported research. Written reviews are required for all projects and representatives of federal agencies involved in marine-related activities are present at annual reviews conducted on university campuses. These site visit teams conduct an indepth evaluation of work underway as well as the work proposed for the coming year. Typically, site visits have representation from one or more of the following agencies: National Marine Fisheries Service, EPA, U.S. Army Corps of Engineers. Written reviews are solicited from these agencies as well as the Office of Education, HEW, and the National Science Foundation.

Interaction with the Research Applied to the Needs of the Nation (RANN) program of NSF has resulted in routine exchanges of proposals.

Within NOAA, the Office of Coastal Zone Management and the Office of Sea Grants coordinate granting and contracting arrangements. The closeness of these two programs makes frequent interaction imperative.

At the state level, program and project reviews are solicited for some research projects. At most university site visits, local representation is arranged. Among the groups asked to review the research programs are representatives from state departments of natural resources, fish and game commissions, state planning offices, marine councils, navigation districts, port authorities, county commissions, and regional councils of government. Sea Grant institutions also seek participation of these groups, along with industrial and academic representation, on their own advisory councils.

As a result of the careful scrutiny given to research proposals, the work undertaken by Sea Grant programs is technically feasible and locally acceptable. This continuing review process assures that universities are meeting the needs of the state without duplicating efforts of other agencies.

CONCLUSION

Careful study of Sea Grant work in support of estuarine quality leads to several observations about future work and about the Sea Grant concept in general.

As American universities struggle through their current identity crisis, many new thrusts are likely to emerge. The university of the future, for example, may assume several roles—an ivory tower of knowledge, a processor of trained professionals and skilled craftsmen, a generator of new knowledge through basic research. In all of these roles, however, the university will become more of an agent for social change, a medium for transmitting information designed to improve the quality of life. In this regard, the university will assume greater responsibility for applied research, blending together old and new knowledge and delivering better alternatives for future decisions. This trend is already emerging, particularly in state-supported institutions; and through partnerships such as Sea Grant, the pace is accelerated.

This trend has been brought about, in some degree, by the recognition of state and federal agencies of the manpower and knowledge resource which universities represent. Tapping these resources is a logical mechanism for tackling many state and national problems. With each new generation of students adding to the knowledge base, universities remain at the forefront of knowledge. As students, professional teachers, and researchers extend themselves into applied and decision-oriented research fields, the total university resource can be brought to bear on identified needs.

The preceding examples of Sea Grant work in environmental quality are evidence of the future of university-based programs which draw together teams of professional scientists, engineers, and social scientists to focus on broad resource issues. The studies are also illustrative of the impact potential when partnerships exist between federal and state interests.

Although much has been accomplished under the Sea Grant banner, its greatest contribution lies in the innovativeness of its approach and the spirit of service which it has sparked in American colleges and universities.

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ESCAROSA: THE ANATOMY OF PANHANDLE CITIZEN INVOLVEMENT IN ESTUARINE PRESERVATION

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ABSTRACT

Florida's gulf coastline measures over 700 statute miles, and has the most diverse estuarine flora and fauna of any state. Because of its growing population and its readily accessible coastline probably no other estuarine system has received pressures comparable to those exerted on Florida's gulf coast ecosystem from 1950 to the present. This paper revolves around the "Florida Panhandle" in general and Pensacola in particular.

Citizen involvement begins through information services provided by newspaper, radio, and TV. In Pensacola, the newspaper media had the greatest impact and long-term effect.

There are a variety of vehicles and mechanisms for citizen involvement and many were brought into play in the panhandle. One of the most effective approaches is through sportsmens' organizations. Homeowners' associations also can be effective vehicles, but they may be self serving and are more subject to varying levels of bureaucracy. Regional planning organizations are a proper vehicle but they are even more dependent upon and subject to government bureaucracy. Governmental advisory groups can be effective if they can maintain good relations with the board tha' appoints them and if they can understand that governments cannot correct overnight the damag.s done by poor planning through decades. Regional, state, and federal hearings are an excellent outlet for citizen pressures.

It is concluded that the Regional Planning Council should be the lead agency in coordinating citizen efforts in estuarine preservation.

INTRODUCTION

Florida's gulf coastline measures over 700 statute miles and has the most diverse estuarine flora and fauna of any state in the United States. The reasons for this diversity are the extraordinary environments and climates found over the 700-mile span. The southern tip of Florida is a drowned lacustrine plain characterized by mangrove swamps and lagoons with lush marine-grass meadows. The mean air temperature is 70°F. in January and 83°F. in July.

Stretching northward from Cape Romano, the coastline changes to barrier islands, sand beaches, and low dunes. Mangroves, tidal marshes, and submarine meadows are major features in the area which also encompasses two major bay systems: Charlotte Harbor and Tampa Bay. The area northward from Anclote Key (Tarpon Springs) is primarily tidal marsh and submarine meadows. The fourth area, and the setting of this particular discussion, is the panhandle of Florida, characterized by barrier islands, high energy beaches, tidal marshes, and numerous bays. The mean air temperature of this fourth area is 53°F. in January and 82°F. in July.[1]

Because of Florida's growing population and consequent development along its readily accessible coastline, there is probably no estuarine system in the nation that has received the pressures suffered by Florida's gulf coast ecosystem from 1950 to the present.[1,6] The locality for this scenario detailing citizen response to estuarine degradation shall be limited to the area entitled "the Florida Panhandle" and centers primarily around Pensacola and Escambia Bay. This area was the site of five federal-state enforcement conferences between 1970 and 1972.[2,6]

The plight of Escambia Bay has received nationwide publicity with newspaper stories and pictures appearing from Los Angeles and San Francisco in the west to Trenton, N.J., in the east.[7,9] In addition, Sports Illustrated classified the Escambia River as one of the nation's 10 dirtiest rivers; Skin Diver magazine's environmental editor, Bill Barada, featured an article on the Escambia story called "Death Trap."[10] Yet all of this publicity is anticlimatic to the roles played by citizens in the area, aroused citizens who already had been doing something about their dying estuarine ecosystems.

The purpose of this paper, then, is to discuss the efforts and achievements of individuals and citizen groups in their struggle for estuarine preservation and the improvement of water quality in northwest Florida. My attempt is to show that citizen involvement has been effective even when it was isolated, unpopular, or smothered by red tape; that citizen action has resulted in positive action which makes the outlook for effective preservation much brighter today than six years ago. I treat the various efforts or groups one-by-one not only for convenience but also for the fact that very little integration of effort or interaction initially took place. I conclude the paper with a recommendation for a means to achieve coordinated, effective, continuous estuarine preservation in the area emphasized.

THE ROLE OF MASS MEDIA IN CITIZEN INVOLVEMENT

Whereas nationwide publicity cited above aroused interest and anger in far-flung corners of the United States, major credit for local citizen awareness should go to the staff of the Pensacola News-Journal. A review of newspaper listings from 1962 through early 1970 tells a very complete story of a responsible press coverage: in 1962, one article; in 1963, seven pertinent articles; in 1964, 13 pertinent articles; in 1967, more than 20 articles detailing growing population problems; in 1968, more than 60 articles and thought-provoking editorials; in 1969, more than 200 continuing stories and editorials detailing the day-to-day castastrophies of Escambia Bay.[12]

Pensacola newspaper reporting by Mike Albertson and Tom Bell together with thoughtful editorials and editorial cartoons directed by Earle Bowden brought awareness and education to the citizenry of the two-county area known as Escarosa. These three men are, in the author's opinion, primarily responsible for providing the major impetus for environmental awareness and continued citizen involvement.

By 1970, the electronic media, both radio and television, began to focus on the problem and open the door to citizen involvement. Of particular note and value was the coverage of station WEAR-TV, an ABC affiliate; not only were viewers exposed to the fish kills in the area waters but also to the subsequent federal-state hearings on their causes and on water pollution in general. That citizen response began to increase could be measured by a radio program, "Pensacola Speaks," carried by station WCOA. Listener after listener, night after night, lamented the pollution problem and asked what might be done. In addition, educational television station WSRE (Channel 23) carried panel

ILLUSTRATION 1

discussions on the pollution question simulcast with "Pensacola Speaks."

VEHICLES AND MECHANISMS FOR CITIZEN INVOLVEMENT

The following discussion will highlight failures and successes of efforts to prevent or correct what might be called the Escambia catastrophe. In addition, it will briefly mention various vehicles and patterns for citizen involvement.

Sportsmen Organizations

In 1968, a group of interested saltwater fishermen organized the Northwest Florida Sports-fishing Association. The membership swelled to considerable

ILLUSTRATION 2

size and a major thrust was to bring about solutions to estuarine degradation in the area. Its principal purpose was to be a pressure group and to a limited end it was successful. However, the association was unsuccessful in raising sufficient funds to get an unbiased study of bay and estuarine pollution. It is difficult to pinpoint the disintegration or demise of the organization, but it coincides with the intervention of federal investigators in the pollution of Perdido and Escambia Bays and the formation of the West Florida Natural Resources Council. Perhaps this sports fishing association felt it had served its purpose; at any rate, citizen involvement began with it in 1968.

Whereas the Northwest Florida Sports-fishing Association began in 1968 and died in 1969, another group of sportsmen were growing concerned about estuarine preservation. The Bream Fishermen Association (hereafter referred to as BFA) was a small, close-knit group of outdoorsmen dedicated to good practices of wilderness protection, preservation, and conservation. These were not men who would be content to be a pressure group only; they were citizens with definite plans of action. They launched their first efforts on behalf of the national seashore in 1969 and received their baptism of political fire from members of the Santa Rosa Island Authority who objected to their attempts to get petitions signed by the citizenry visiting the beach. Their next major effort was in early 1970. They felt that there was too much talk and not enough action concerning actual biological conditions in the once fertile interface between Escambia River and Escambia Bay. During April, May, and June, 1970, the BFA spent over a thousand man hours conducting a voluntary creel census to document fishing and its results on the Escambia River—a task long neglected by any state agency. The results and conclusions of this census were far-reaching and the enthusiasm of the association recruited new citizen-scientists to its cause. The results were made public in 1971.[13] In a nutshell, analysis of 1,234 different fishing trips involving 2,558 fishermen showed that the average fisherman would catch one fish for two hours' effort and its average weight would be less than a quarter pound! This creel census was only a starter, however, for the BFA also set about to correct matters in an amazingly effective program for 1970.

Convinced that the conditions in the lower portion of Escambia River could be improved by several means, the BFA (1) started a night pollution control program, (2) bioassay stations, and (3) a fish feeding program.[14]

The night pollution program was not just a militant conservation group's idea of harassing industry. The BFA knew full well that the state agency responsible for monitoring pollution simply did not have enough manpower to be everywhere at once—especially at night. A keynote of BFA's success was early detection of a break in a flyash holding pond at a local, coal-burning electric power plant in December, 1970. Along the same lines, bioassay stations were established and maintained in and near industrial outfalls. In both cases, recorded data was turned over to the responsible parties involved. The fish-feeding program stemmed from the fact that water quality was so poor that fish either would not spawn or, equally bad, their fry would not have sufficient food. BFA members bought over 2,000 pounds of commercial fish food and distributed it on the spawning beds.

In appreciative response, local merchants applauded BFA's courageous efforts and donated a new fiberglass boat, an outboard motor, gasoline, oil, and boat landing services. BFA and its citizen army was on the move.

In the spring and summer of 1971, the "night patrol" turned into the "dawn patrol" as BFA monitored the tidal marsh headwaters of Escambia Bay, collecting data on dissolved oxygen temperature and fish kill conditions. Not only were actual fish kills located in the bay, but also an early warning system was devised. This monitoring program was maintained through 1973 and resulted in valuable data concerning tidal flushing (stagnation) by upper bay waters which infiltrate the tidal marshes.[15,16]

During 1972, BFA made a major effort over a one-year period to document species diversity in the river immediately below the Jay Oil Field adjacent to the Escambia River in north-central Santa Rosa County. With the help of a grant from Humble Oil to the University of West Florida, the association developed a complete faunal inventory of the potential impact area. Such information is not yet generally available but will be of considerable value in assessing the impact of an oil spill on the upper estuarine area. In this project, 40 BFA members worked a total of 3,489 hours in the field![17,18]

BFA activities continued to mount in 1973. Members discovered that yellow bullheads in the Yellow River system are subject to an important melanoma cancer, a fact that proved of interest to both the Environmental Protection Agency and the Smithsonian Institution. During the Oil Field Study, BFA took coliform samples in the river to establish coliform levels and origins prior to bay entry. Members acted as environmental lobbyists to prevent Getty Oil Company from exploratory drilling in East Bay, and the association alertly filed protests with the EPA in Atlanta concerning proposed expansion of Pensacola's northeast treatment plant which was already discharging into an overly-enriched Escambia Bay. This timely protest resulted in the decision that the northeast plant cannot be expanded without concurrence and approval of EPA and the approved Water Quality Management Plan being prepared for the two-county area through the Regional Planning Council.[18]

The year 1974 brought even greater BFA activity in estuarine preservation. BFA members gave material assistance to the EPA Escambia Bay Recovery Team by providing manpower for transplanting marine grasses in the upper estuary. On another cooperative front BFA members aided the Department of Pollution Control by collecting sorely needed data on Perdido River and Bay.

On the lobbying front, the organization has been very effective on several issues: (1) diking Yellow River flood plains; (2) continuing opposition to expansion of Pensacola's northeast treatment plant on Escambia Bay; (3) writing formal objections to the Corps of Engineers on matters of estuarine resource preservation; and (4) filing a court injunction resulting in a favorable ruling against the introduction of "Asian Grass Carp" into Deer Point Lake on the grounds that this species could easily escape from that system and enter northwest Florida's estuaries.[19,20]

In summary, the Bream Fishermen Association's efforts prove that sportsmen organizations can be successful in activities involving estuarine preservation. The key ingredients in these activities are leadership, initiative, and energy. As demonstrated above, the BFA, a citizens' organization, has taken an exemplary leadership role in working in the field with local, state, and federal agencies; in keeping citizens aware of threats to northwest Florida through its "Conservation Newsletter" and displays at the county fair; and in political lobbying.

Homeowners' Associations

Although it may be argued that homeowners' associations, like industries, have a vested interest in estuaries, homeowners on estuarine bayous, bayfronts, and waterways seem to be positively motivated toward good water quality. In the panhandle area we can document some interesting cases of homeowner involvement with estuarine preservation.

Mulatto Bayou-Avalon Beach homeowners.—The mouth of Mulatto Bayou, a bayou historically important as a nursery area on the east side of Escambia Bay, was severely altered in the construction of Interstate 10 bridge across Escambia Bay.[20] After completion of the project, a new access to the bayou was provided. Homeowners in the area, however, used various means of political pressure and lobbying to get the State of Florida to correct silting in the bayou proper.[21] They argued, incorrectly I believe, that the construction activities had caused the main portion of the bayou to become silted in. I met with the homeowners and showed them reasonable proof that the origin of their problem was not road construction, but improper dredging activities by a real estate developer. After a great deal of discussion, the homeowners became aware that the desired dredging could create even more damage to the system which they wanted so desperately to correct.[22] But their awareness and understanding came too late. The State Department of Transportation had already let bids and issued a contract to an out-of-state dredging company.[23] Last minute letters to state agencies involved were fruitless.[24] Although a hearing was held at the request of the Federal Water Pollution Control Administration because the dredging would be in violation of conferees' rulings, the Corps of Engineers did not cancel its permit and the Mulatto Bayou area was dredged, with disastrous results.[25]

In this example, the homeowning citizens had the best of intentions; their efforts, however, resulted in a death blow to a system struggling to survive.

Perdido Bay homeowners.—Perdido Bay receives a large amount of effluent from a kraft pulp plant located at the head of the bay. Perdido Bay also has received large amounts of poorly treated sewage through Bayou Marcus Creek. The bay is divided by the state line of Florida and Alabama. Although the kraft mill waste and sewage originate in Florida, Alabama residents headed by Mrs. JoAnn Allen strongly have contended and demonstrated that these pollutants reach their shores. Mrs. Allen has courageously maintained pressure not only on officials in Florida and Alabama but on federal officials in Atlanta, Ga., as well. Her efforts were at least partly responsible for Alabama's request for a full-scale investigation in 1969 and continued hearings into the present. Although some of the problems are not fully corrected, the water quality of Perdido Bay is markedly improved as a result of the continuous vigilance and relentless lobbying of this untiring Alabama resident.[2,4]

Bayou Texar Association of homeowners.—Bayou Texar is an estuarine subsystem of Pensacola Bay. It is within the Pensacola city limits and receives its primary sources of freshwater from Carpenter's Creek whose headwaters are outside the city limits. To begin with, Carpenter's Creek has been severely abused by channelization and suburban development. In addition, it is a major recipient of septic tank seepage, lift station overflow, storm sewer drainage, and ordinary runoff from streets, yards, and parking lots. As a result, it has in the past 10 or 15 years carried an immense load of silt, organics, and elemental nutrients into the bayou proper. A worsening situation compounded by outdated sewer lines and a malfunctioning lift station caused the homeowners around the bayou to begin lobbying city government for environmental relief. In addition, they approached the University of West Florida for guidance and scientific advice[26] and provided funds for small-scale research. With the Bayou Texar Association research funds behind him, and the association endorsing him, Dr. Gerald A. Moshiri of the university succeeded in capturing the interest of the Office of Water Resources Research (OWRR) on the causes of nutrification.[27,29] But even after basic research was funded by OWRR, the association members did not rest their case. They have donated time, space, and facilities for the completion of the research. Further, they have maintained their pressure on both the city and the county to correct the problems in the drainage basin and around the bayou. In addition, they have secured a special engineering study designed to provide some approaches to the restoration of a severely damaged estuarine area.

Woodland Lake homeowners.—The Gulf Breeze peninsula is a large finger of land projecting westward into Pensacola Bay. At its westward extremity are three bayou ecosystems: Hoffman's, Gilmore's, and Woodland Lake Bayou. As eutrophication levels in Escambia Bay and Pensacola Bay reached peaks, their nutrient-rich waters began to permeate and stagnate in these estuarine bayous. Following the lead of the Bayou Texar Association, the Woodland Lake homeowners approached the university in 1971 via Dr. Sneed B. Collard of the biology faculty.[30] Through Dr. Collard, a scientific approach to restoring the bayou was designed. With methodical care, the Woodland Lake Association began the necessary lobbying process through local, state, and federal officials. Records indicate that the Corps of Engineers generally investigated the restoration project but could not fund it.[31] The state Department of Pollution Control endorsed it as a "model project" and commended it to the Environmental Protection Agency.[32,33] The regional office of EPA seems to have liked the proposal and forwarded it to the Washington office.[34] After over a year of revising, endorsing, revising, and resubmitting, all came to nought when the Washington office of EPA notified the city of Gulf Breeze that "the model project" endorsed by so many "does not directly fulfill our high priority research needs" and that they could not support the project.[35] This was the culmination of almost two years of citizen effort. A less dedicated group of citizens might have given up, but not these.

The city of Gulf Breeze still backs the bayou restoration and the citizens themselves are putting their dollars and their hands to the task of clearing the choked opening to the bayou that has developed. After natural flushing is restored, the members must face the benthic sludge problem and the long, slow process of removing it. Their optimism is overwhelming—they will restore Woodland Lake Bayou in spite of the odds and the bureaucratic heartbreaks over the months. They optimistically look for the day when the shrimp and fish return to their restored estuarine ecosystem.

Regional Planning Organizations

West Florida Natural Resources Council.—Formed in June, 1969, by executive order of Governor Claude Kirk, Jr., the West Florida Natural Resources Council (WFNRC) was an ambitiously precocious attempt to establish coastal zone management in the Florida panhandle. It probably grew out of (a) the obvious conflicts in coastal zone use; (b) the very thought-provoking editorials of the Pensacola News-Journal which called upon the University of West Florida for leadership in environmental investigation;[36] (c) the interests of an estuarine-oriented biology faculty; and (d) the farsightedness of Dr. Harold B. Crosby, its first chairman. In a presidential memo dated July 8, 1969, Dr. Crosby, former president of the University of West Florida, explained to the faculty, "Many factors combined to make it necessary and desirable to establish such a council. Amongst them is increasing concern of the people of West Florida over water pollution and the apparent changes in physical and biological quality of the coastal and estuarine environment." The charges to the council were specifically as follows:

1. To establish in the West Florida region at the earliest practical time, under the control and supervision of the council, task forces to recommend and implement plans:
   (1) for the study and abatement of the water pollution problems of Escambia and Santa Rosa counties;
   (2) for the study and abatement of the dog fly;
   (3) for the study of Choctawhatchee Bay and related waters.
2. To establish a data bank at The University of West Florida relating to water pollution, dog fly, and estuarine studies and provide for information dissemination program.
3. To develop a unified interagency (local, state, and federal) and interstate effort to investigate and solve the above listed problems in a systematic fashion.

The first meeting of the council was held June 1969, with Governor Kirk in attendance. Chairman Crosby moved quickly to establish council committees and to organize task forces (a table of organization appears in Figure 1). It should be stressed that this organization was considerably more than a hastily organized group of scientists, politicians, and community leaders gathering together for a common cause: estuarine preservation and coastal zone management.[37]

Council meetings were open not only to the public but also to agency officials who attended and participated in meetings. Congressman R. L. F. Sikes expressed his support and in fact acted on the council's behalf in Washington, D.C.[38]

By August 15, 1969, the West Florida Natural Resources Council was ready to approve budgets totaling over $700,000 for the various task force operations, as follows:[39]

Escambia-Santa Rosa Pollution	$150,000
Choctawhatchee Bay	203,306
Dog Fly Control	356,670

Local citizens, however, were critical of the proposed allocations. It appeared to them that dog fly control and tourism were more important than "clean water." Although this reaction reflected accurately some local attitudes, the council was simply hearing and acknowledging proposed first-year costs. The question of where the money would come from was still to be examined.

The first task force to make a report of progress to the council was the Escambia-Santa Rosa Water Pollution Task Force which on October 8, 1969, reported to the eager citizenry that Escambia River and Bay were grossly polluted and that the major polluters were three local manufacturing industries and the local power generating plant.[40] This report was delivered to a standing-room-only council meeting and it was what the area citizens were anxious yet fearful to hear. Relatively clear answers to questions that the Pensacola News-Journal had asked previously and with increasing tempo were provided to the citizens that day. The report gave them a springboard for involvement.

At the same time that the council was establishing its credibility and achieving local praise for its efforts, unforeseen and intangible difficulties were beginning to take a form that would bring about the ultimate demise of this laudable attempt to establish approaches to coastal zone management. These forces are not unrelated:

1) *Lack of fiscal support.* Although the West Florida Natural Resources Council had been in operation over four months, it did not have a meaning-

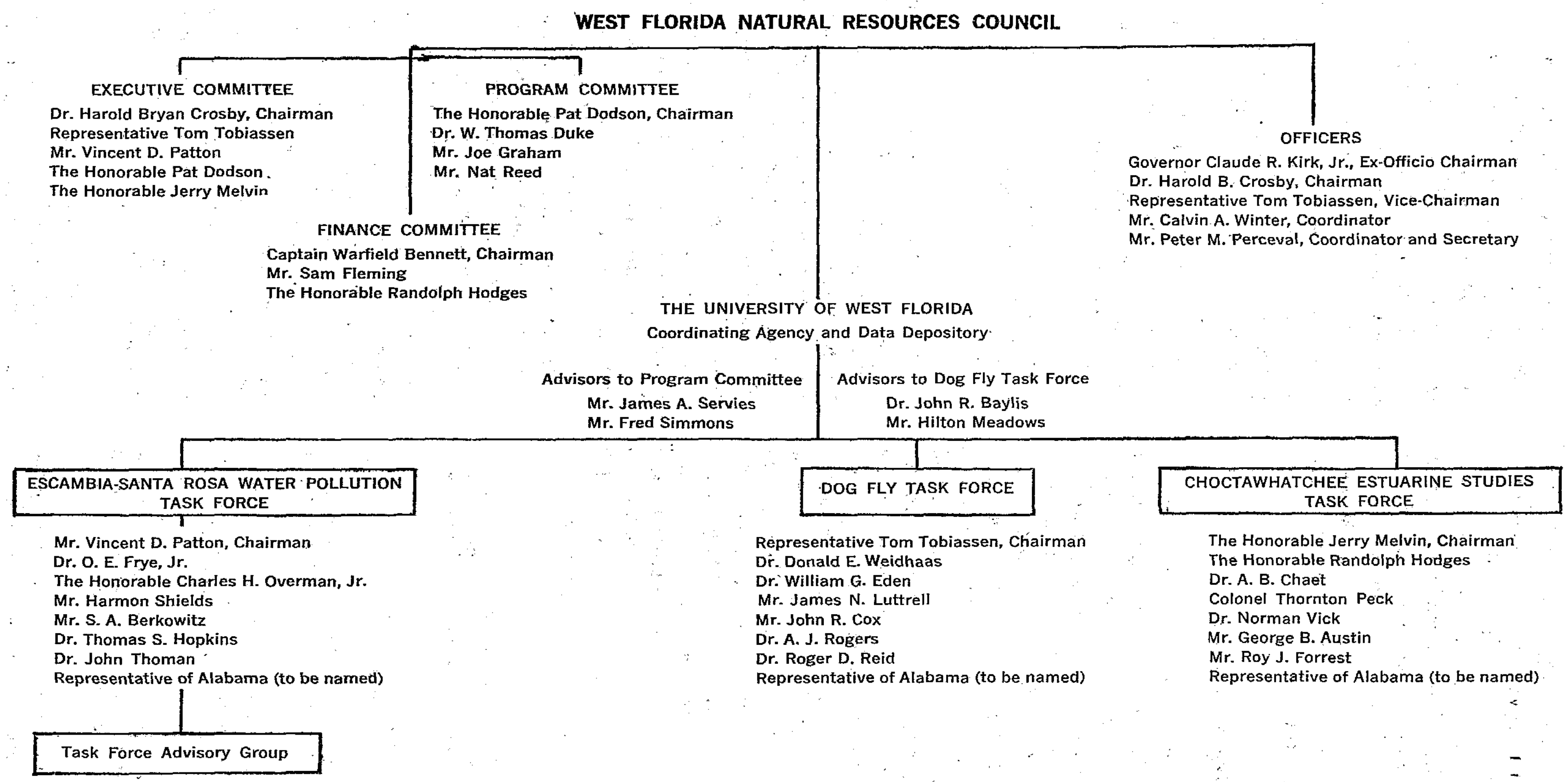

FIGURE 1.—Organizational diagram for the West Florida Natural Resources Council (now defunct).

ful "bankroll" to support any of its task forces. In addition, its own administrative costs were growing.

2) *Governmental reorganization.* The State of Florida consolidated several agencies and clarified certain roles in environmental protection, which probably destroyed the previous vacuum in coastal zone responsibility.

The fiscal woes of the council increased as the new state agencies jockeyed for larger budgets and operating room. It became clear that the WFNRC and its concepts so strongly endorsed in June were taking a back seat by December 1969.

President Crosby provided new life for the council in May 1970, by appointing Dr. Joe A. Edmisten as director of the council and coordinator of Coastal Zone Studies.[41] Fiscal problems continued to plague the council and by July 1970, only about $43,000 of the needed $700,000 had been found and allocated. For the Escambia-Santa Rosa Water Pollution Task Force, $18,000 was provided by the Department of Pollution Control; $25,000 was provided for the Dog Fly project from other state funds. But in spite of this limited funding, citizen involvement continued and it was during this period that the Bream Fishermen Association (BFA) joined the "clean water" task force. At this time, the WFNRC was optimistic that more funds would be found.

The council met in August to hear a proposal for a "coastal zone inventory" and urged the Department of Natural Resources to adopt a uniform inventory plan.[42] This resulted in Dr. Edmisten urging Governor Kirk to declare the Escambia Bay a natural disaster area, "To become eligible for federal aid in the form of grants and loans designed to help fishermen and shrimpers of the area stay in business . . . until we are able to restore Escambia Bay to its original healthy state."[44] The council's executive committee explored this possibility in September 1970, with many citizen groups being represented. After considerable debate, it concluded that the area was not eligible for federal funds.[45] The council met again in October 1970, and learned that the newly formed Coastal Coordinating Council (CCC) operating out of the Department of Natural Resources was implementing a plan for a statewide uniform inventory of natural resources. The CCC would start its plan using Escambia and Santa Rosa Counties as a pilot area called "Escaros." This appears to have been the last real meeting of the council.[46]

In summary, the West Florida Natural Resources Council was born in a time of need and undoubtedly realized some major achievements in citizen involvement and estuarine preservation. It died slowly but steadily as other state agencies increased their activities and manpower resources in the panhandle region.

West Florida Regional Planning Council.—The West Florida Regional Planning Council (WFRPC) was created in 1964 under the authority of chapter 160 of the Florida Statutes. Starting as a one-city one-county agency, the planning council now serves three counties and many municipalities.[47]

In the area of estuarine preservation, the state has designated the WFRPC as the planning agency for "Development of Regional Impact in Escambia, Santa Rosa, and Okaloosa Counties." At the federal level it has similar designations, particularly in the area of water quality management where this policy interfaces with the Environmental Protection Agency in comprehensive planning. Although the WFRPC has a professional staff its operations are governed by a citizen board representing the cities and counties under the WFRPC umbrella.[47]

One of the major achievements of the regional planning council was the development of water quality management for Escambia and Santa Rosa counties. This plan was funded under Section 3c of the Federal Water Quality Act of 1965. The grant application was filed in 1972 and work began. The plan is oriented toward estuarine preservation and is cost effective. Its goal is to significantly reduce the amounts and richness of surface discharge into estuarine areas.[48,49]

In addition to the plan cited above, the regional planning council acted as a coordinating agency to develop a plan for the restoration of Bayou Texar, cited earlier. The council also works with projects in the three-county area involving prospective development—e.g., what impact a large multi-service shopping mall and its collective runoff will have on the estuarine receiving waters.

In summary, the WFRPC is a citizen board with responsibility for regional planning in a geographically complex estuarine area. Its professional staff and citizen board are called upon to make far-reaching decisions.

Governmental Advisory Groups

County Commissioners' Pollution Advisory Committee.—In the fall of 1970, after another year of disastrous fish kills, citizen outrage, and editorial comment, the county commissioners of Escambia County followed a recommendation offered by Wayne E. Tisdale, regional engineer for health and rehabilitation services, and created an advisory committee.[50] The citizen select committee was chosen to represent business and commerce, sport and commercial fishing, industry, agriculture, the legal profession, and education. Acting Commission Chairman Sam Armour, "charged the committee with its responsibility to seek solutions to the pollution problems in Escambia County and to advise the Board of County Commissioners accordingly . . ."[51] The committee, hereafter referred to as ACOP, began to meet weekly and many citizen manhours were invested. It heard presentations by regional engineers from two state agencies, the county environmental health director, and several concerned citizens who reviewed the environmental problems from their viewpoints. In addition, the committee mailed out three questions to selected citizens in the community for written responses. These questions were as follows:

(1) "How to Stop the Present Pollution of Our Environment"—Please outline any constructive solutions you may have relative to the air and water pollution of Escambia County. Of particular value will be specific technical/legal recommendations that can be implemented immediately by Escambia County.

(2) "How to Prevent the Pollution of Our Environment in the Future"—Please outline any constructive solutions you may have relative to preventing pollution in the future. Recommendations relative to air and water quality standards for new industries, expansion of County and City sanitation facilities, etc., will be of value.

(3) "How to Restore the Damage Done by Past Pollution Practices"—Past and present pollution practices have seriously damaged many of our areas. These areas must be restored to some reasonable resemblance of their original quality. Recommendations for their restoration (clearing the bottom, restoring fish and aquatic life, etc.) are requested. In addition, your ideas on how to fairly distribute the cost of such restoration would be appreciated.

The committee's purpose was to get as comprehensive a response as possible so that meaningful recommendations could be made to the county commissioners. In addition, the committee established several citizen subcommittees. For example, a "Solid Waste Disposal" subcommittee was set the task of studying how the county landfill was contributing to the pollution of Perdido Bay.

The Pollution Advisory Committee was very forthright and set to its task with considerable zeal. For example, in its first 30 days, it developed a series of thoughtful, action-oriented recommendations dealing with the estuarine environment.[52] Although recommendations were rarely adopted by the county commission, the thrust of the committee created beneficial side effects and interest on the part of the commissioners themselves. For example, the commissioners held hearings concerning the establishment of nutrients and thermal discharge limits. This procedure allowed industry representatives to present their views with citizens in attendance.[53]

Although the advisory committee was frustrated in attempts to establish regulations for local industry, it was very successful in negotiating safe practice regulations for the Humble Oil and Refining Company which was requesting permission to install pipelines in the delta region of Escambia and Perdido Bays. Indeed, the attentiveness and cooperation given by the Humble Oil Company in meeting with citizen committees might serve as a model for other agencies seeking permission to carry out potentially deleterious projects in the estuarine area.[54]

The advisory committee pursued its regulatory interests in 1971, working closely with the Department of Pollution Control and developed a model local program which was unfortunately tabled.[55,56] On the plus side, however, was the opportunity for citizens to interact with state officials in a constructive way to bring about estuarine preservation.

In 1972 the Escambia County Commission was reorganized, and the new chairman created a new citizens organization called VOICE (Voices of Interested Citizens of Escambia). Although the Advisory Committee on Pollution (ACOP) was allowed to continue, it became apparent that it would be akin to a forgotten stepchild. Nevertheless, the committee has continued to meet and act on matters referred to it by the commissioners. Ironically, the county commissioners reorganized again in 1974, and the new chairman has indicated that the services of VOICE will be discontinued. The fate of ACOP has not been announced.

In summary, the Citizen's Advisory Committee on Pollution matters in Escambia County was created in response to citizen concern over rampant environmental degradation in the county. The committee was very active in its initial year of operation, but as is so often the case, a citizens' committee is quite capable of recommending solutions which are beyond financial, legal, or political grasp of the local, state, or federal government agency to which it reports.

Technical Advisory Committee, West Florida Regional Planning Council, Water Quality Management Plan.—Without going into great detail concerning this activity, it should be noted that the Water Quality Management Plan cited earlier was developed through the guidance and approval of a committee containing not only local, state, and federal professionals but lay citizens as well. Serving on this committee were citizen advisors Clyde Richbourg of the American Seafood Company, and Tony Raibl, representing the Bream Fishermen Association.

Regional, State, and Federal Hearings

Earlier, I referred briefly to hearings at the county level resulting from efforts of the County Commissioner's Advisory Group. State and federal agencies have held hearings also, and these hearings are a meaningful outlet for citizen concern and education. Enumeration of three such hearings follows.

Regional Planning Council Hearings.—The West Florida Regional Planning Council held a series of public hearings concerning the Water Quality Management Plan. Although these hearings were advertised in the newspaper and on TV, they were rather poorly attended. The final hearing in May 1974, attracted only 54 people, including participants.[49] This number is less than 0.1 percent of the city of Pensacola's population, much less of the two-county area represented. It would appear that with pressures of the economic recession we are in, citizens are turning their backs on interests and concerns of four years ago. This probably will be evident in federal hearing attendance data as well.

State Agency Hearings.—The scenario for hearings concerning Escambia Bay begins earlier than 1969. However, the first major hearing which drew a sizeable citizen turnout was on May 21, 1969. At this time, the Florida Air and Water Pollution Control Commission with Governor Claude Kirk, Jr., in attendance held a hearing entitled "Investigation of Water Quality in Escambia River, Escambia Bay, Pensacola Bay, and Perdido." Presentations were made by four state agencies, the city of Pensacola, and the state of Alabama. Several persons asked to be heard and were granted appearances. These included the chairman of the Pensacola Anti-Pollution League and a representative of the Florida Wildlife Federation. The hearing, well-attended for the time, drew 150 persons.[57,58]

Federal Agency Hearings.—Beginning in January 1970, the Federal Water Pollution Control Administration, which held hearings on Escambia Bay on January 21 and 22, began a series of enforcement conference hearings concerning water quality in Escambia Bay and Perdido Bays.[2,6] Although the 1970 hearing on Escambia Bay attracted over 290 participants, the second session on February 23, 24, 1971, attracted less than half the previous number and the third session on January 24–26, 1972, showed a further decline in audience participation. This decline in attendance is regrettable, for such hearings are vital to estuarine preservation. Federal agencies should be encouraged to report in open hearings what they are doing about their agency-stated goals, and citizens need an opportunity to tell federal and state officials what concerns them. Even though some citizen concerns may be ephemeral on the one hand, and state and federal action or processes slow on the other, constant and better communication is imperative. In this regard, it is unfortunate that the Escambia-Perdido Bay conferences have not been reconvened each year and that many citizens believe that such enforcement conferences have been unsuccessful in bringing about any real change in pollutants and water quality.

Miscellaneous Clubs and Other Organizations

During the period of greater citizen concern over Escambia Bay, there was a great deal of organizational interest from the standpoint of group education. Additionally, many of these groups or organizations actually mobilized in force to attend hearings, workshops, or write letters. Not wishing to ignore or play down the role of any citizens' group, I want to acknowledge the contributions of those organizations that I can recall which were interested and active:

Sierra Club of Pensacola
National Wildlife Federation, local chapter
Frances M. Weston Chapter, Audubon Society
Save-Our-Beach Committee
Florida Federation of Garden Clubs
League of Women Voters
Pensacola Womens Club
Junior League of Pensacola
Pensacola Junior Chamber of Commerce
Rotary of Pensacola
Kiwanis of Pensacola
Greater Pensacola Chamber of Commerce
Choctawhatchee League for Environmental Action Now (CLEAN)
Gamefish Protection Association (Okaloosa-Walton County)

All of these organizations and perhaps others as well were concerned enough to invite me, enforcement officials from state agencies, or industry spokesmen to meet with their groups so that they could become acquainted with estuarine problems. Of the above groups, the Sierra Club of Pensacola is currently the most active in preservation.

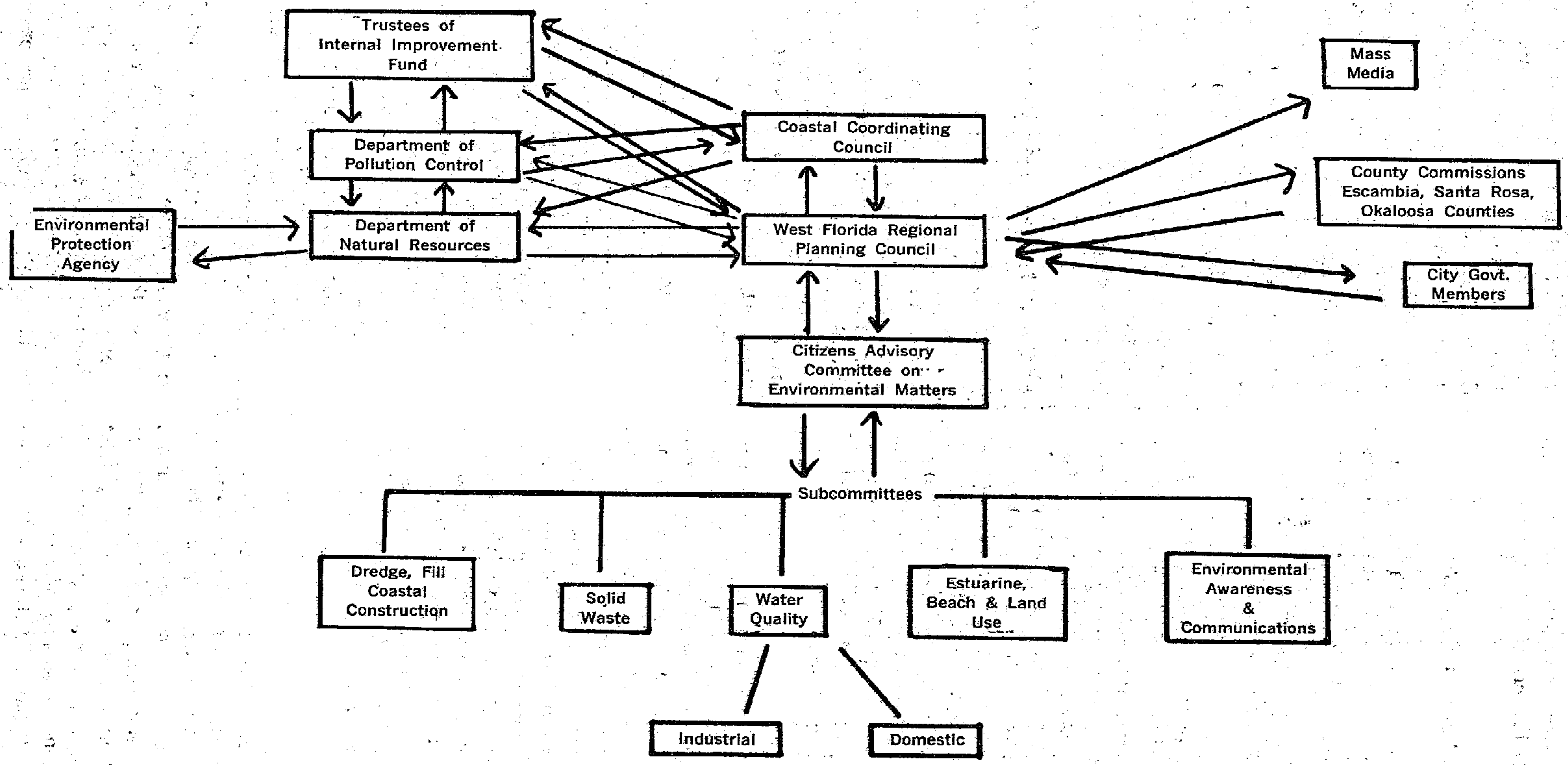

FIGURE 2.—Flow diagram showing how the West Florida Regional Planning Council could consolidate citizen involvement.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. This paper has discussed the background and context of citizen awareness and involvement in estuarine preservation in northwest Florida.

B. Vehicles and mechanisms for citizen involvement are through (a) sportsmens' organizations, (b) homeowners' organizations, (c) planning councils, (d) local, state, or federal advisory groups, and (e) attendance at local, state, and federal hearings. Other routes of involvement include civic clubs, conservation groups, and semi-professional societies.

C. In all cases, there are certain pragmatic, legal, fiscal, or economic issues that influence the success of the concerned individual or organization.

D. Considering these realities, it is proposed that the best avenue for estuarine preservation in the geographic locale of northwest Florida would be through the West Florida Regional Planning Council (Figure 2 shows schematically how the Regional Planning Council concept would be applied). It should be noted that if the WFRPC assumed this added responsibility, additional staffing would be a necessity. On the other hand, use of this existing agency would seem to be the most cost effective and would be consistent with its legislatively mandated role. Furthermore, it is the agency most closely in tune with the Coastal Coordinating Council which would be responsible for the implementation of Coastal Zone Management in Florida.

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THE ROLE OF THE PUBLIC IN TEXAS ESTUARY PROTECTION

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ABSTRACT

The projected superport inside the South Texas bay system at Harbor Island, near Corpus Christi, stirred public indignation to a high level. Here is the way the people of South Texas reacted—and the methods they used to make their voices heard.

INTRODUCTION

The Texas coast is, historically, the most unappreciated part of Texas.

Texas is land, lots of land—267,339 square miles which form a highly individualistic link between the Old South and the Rockies and between the Great Plains of the Midwest and the subtropics of the U.S.-Mexico border. It is more than 800 straight-line miles from the northwest corner of the Texas panhandle to the southernmost curl of the Rio Grande below Brownsville. The east-west distance from the broadest bend of the Sabine River to the pointed tip above El Paso is almost as great.

If all states were as big as Texas, there would be only 13 states. There is room enough in Texas for 220 states the size of Rhode Island or six states the size of New York. The largest of Texas' 254 counties is almost as big as New Jersey. If a state were molded to the same size and shape as Texas and placed directly east of Texas, it would reach 35 miles into the Atlantic Ocean beyond St. Augustine, Fla. A state cut from the Texas pattern and located directly west of Texas would extend 160 miles into the Pacific Ocean beyond San Diego, Calif. Texas above itself would come within 50 miles of the Canadian border. Beaumont, some 25 miles west of the Louisiana border, is nearer to Sarasota, Fla., than it is to El Paso. And El Paso is nearer to Los Angeles, Calif., than it is to Beaumont. Dalhart, at the top of the Texas panhandle, is closer to Pocatello, Idaho, and Billings, Mont., than to Brownsville.

Texas is crops and cattle and mineral wealth—and all the economic, manufacturing, industrial, and metropolitan muscle such broad-based elements of prosperity can be expected to produce. For 38 consecutive years Texas has been No. 1 among the states in mineral output. It is first in petroleum production and first in petroleum refining. More than one-fourth (26.5 percent) of all crude oil refining in the United States is in Texas. Texas refines more crude oil than the total amount refined in California and Louisiana, the second and third ranking states. More than 35 percent of the proved natural gas reserves in the United States are in Texas. Both agriculture and ranching are multi-billion-dollar annual businesses. Texas usually leads all states in producing cattle, sheep, lambs, goats, cotton, and grain sorghums. It competes with Louisiana for first position in rice growing.

Today, the mythical concept of Texas and Texans remains rooted to the wide open spaces despite the fact that Texas has become one of the most urbanized of all states, powered not by rugged individualism but by big-dollar economics and a prosperity-nurtured growth mania. In 1940—barely a generation ago—Texas had a population of 6,414,824 and was predominantly rural. By 1970, the population had grown to 11,749,100, and four of every five Texans (79.7 percent) lived in urban areas. There are 24 standard metropolitan areas in Texas—approximately 10 percent of the United States' total. There are two Texas metropolitan areas among the top 20 in the United States and 10 Texas cities have populations of 100,000 or more. Six metropolitan areas are on the Texas coastal plain, including three cities with 100,000-plus population.

In the 1920s, Houston advertised itself as the place "where 17 railways meet the sea." The slogan was right on target. Galveston, with its island location and natural harbor, had dominated shipping and commerce on the upper Texas coast for decades. In 1914, Houston was handed its chance to emerge commercially when a ship channel was dredged from the Gulf of Mexico inward across Galveston Bay and up Buffalo Bayou. Galveston had the better location but Houston had the better connections with inland points. The ship channel, it turned out, compounded the Houston growth impact by providing a settling strip for industries with a need for deepwater dockage and plant space.

The ecological atrocities, both along coastlines and across inland expanses, can be traced historically to the frontier concept that mankind and the environment are natural adversaries. The concept was an implied part of the manifest destiny credo that the land was there to be conquered and used and not necessarily understood. The shaky status of civilization on the front fringe of the advance across the North American continent gave impetus to this fundamental concept. If the inlands or the shoreline were respected, the degree of respect was measured by the degree of hazard imposed by the environment and not by the environment's intrinsic worth. It was only when mankind achieved a stranglehold on the environment and began converting conquest to excesses that the need to live in harmony with environmental resources came into focus.

Texas, rich in land and rich in both surface and subsurface resources, has grown by the frontier ethic of environmental conquest and has prospered handsomely. Houston has raised itself from its humble beginning as a shaky real estate promotion with a political hue to become one of the great cities of the world. Currently, Houston is the sixth largest city in the United States. By the start of the 21st century, just 25 years away, it easily could rank second only to New York. Already its position as one of the nation's four great anchor cities—New York in the east, Los Angeles on the west coast, Chicago in the north-center position, and Houston in the south-center—is assured. Nearly 400 corporations now make their headquarters in Houston and Buffalo Bayou is as busy as Main Street as ocean-going tankers and cargo vessels move to and from the docks of industrial installations crowded along its banks all the way to open water. Channel dockage space is so much in demand that branch channels are being shaped into the mainland to meet the requirements of still greater industrial development.

Houston is not the sum of it all, but the Houston growth saga has been an inspiring certification of the conquest concept for other communities along the Texas coast. Deepwater channels invariably attract industry and, at least during the free-wheeling fifties, engendered dreams of million-plus populations. Corpus Christi, reached by a deepwater channel in the late 1920s, bounced from 16th to 6th place among Texas cities between 1940 and 1950. Jefferson County, with upstream deepwater at Port Arthur and Beaumont, rose into the top half-dozen Texas counties in population by 1960. Brazoria County, with deepwater at Freeport, has more than quadrupled its population since 1940. The deepwater urge so possessed Brownsville that a channel was fashioned across a tidal prairie for a distance of nearly 20 miles, creating the illusion that ships, somehow, were crossing unbroken grazing land. Point Comfort, in Calhoun County, likewise became a deepwater port, and Galveston County, without space for industrial expansion on Galveston Island, settled for industrialization, with deepwater access, on the nearby mainland at Texas City.

The Texas coastline, by its dimensions and construction, accommodates economic and urban exploitation. It is a long coastline—a great arc reaching 367 miles from the Sabine River on the Louisiana border to the United States-Mexico boundary at the mouth of the Rio Grande. The coastline meanders mightily, following the contours of countless bays sealed from the splash of the Gulf of Mexico by a chain of narrow islands and peninsulas. If the Texas coast is measured by every twist and turn of the shoreline, its length is 624 miles.

The Mississippi River and its tributaries form a gigantic funnel which drains the entire national heartland, diminishes the rivers of the Deep South, and furnishes a flow that dominates and shapes the Louisiana coast. Texas, for the most part, is outside the Mississippi basin and beyond its influence. Instead of being beholden to a single river system, the Texas coast is fed primarily by eight river systems, most of which empty into bay systems of some complexity. The bay systems are, in one fashion or another, connected to the gulf by inlets between islands and peninsulas.

The Texas coastal islands and peninsulas actually are barrier bars—the work of waves which break on the continental shelf. The shelf reaches miles offshore and follows the contour of the mainland in a rather irregular fashion. Because the water above the shelf is relatively shallow, the waves scrape bottom, break, and cast their load of sand particles forward. The sand deposits build into bars which eventually grow into islands. Tidal inlets form where water breaks across the barrier bars in times of storm. Accumulations of marsh grass and silt between the bars and the mainland, where bays and lagoons run thin, turn some islands to peninsulas. There is evidence that some mainland ridges were prehistoric barrier islands which established total links with the existing land mass.

The estuarine settings of the Texas coast—where river flow and the wash of the gulf have achieved a delicate balance—have proved attractive to settlement and, as already indicated, handy for industrial and urban exploitation. The inlets from the gulf are easily pierced to create deepwater channels. The rivers offer sources of freshwater attractively controlled by dam construction. Every stream is a potential channel and every river mouth has possibilities as a turning basin. From the vast surface resources of Texas come fodder for ocean-going freighters. Mineral resources provide the crude oil which makes possible coastal refining complexes, and natural gas provides power for plants which broaden the industrial productive base.

Not every community along the Texas coast can have deep water. There just are not enough inlets from the gulf to turn the deepwater dream into every town's reality. For those who must settle for less, there is the Intracoastal Canal, which cuts across protected waters and marshlands of the landlocked bays and lagoons all the way up the Texas coast. The Intracoastal Canal continues across the southern swamps of Louisiana to the Mississippi River and coastal points to the east. Harlingen and Victoria, both on the coastal plain but a few miles removed from coastal bays, have settled for barge canals. Raymondville, likewise removed, has built Port Mansfield on the shore of Texas' southernmost lagoon and has engineered a barge channel through the center of Padre Island to the gulf. Even Dallas, some 200 miles removed from the gulf, dreams of a coastal connection by turning the Trinity River into an elongated barge canal.

The Texas shrimp and fish business is a multimillion-dollar enterprise, but so great is the industrial overshadow that commercial fishing hardly is visible. Tourism is a late arrival, primarily because the economy already had plenty to go on. Yet despite industrial overkill, municipal malfeasance, official neglect, and public indifference, Texas' estuarine resources still are sufficiently substantial to fight for—and people by the thousands are becoming aware of that fact.

THE PUBLIC STEPS IN

Houston, as a city, is a shining example of urban success. The way Houston has treated its access to the Texas coast is less than exemplary. It is frightening.

Buffalo Bayou originates west of Houston, passes through the city, widens into a turning basin and channel, then winds its way eastward to the northern niche of Galveston Bay. The bay is one of the largest estuarine areas along the Texas coast, gathering, in addition, the waters of the San Jacinto and Trinity rivers.

Buffalo Bayou must be the filthiest stream in the world. Years ago an investigator for Harris County pronounced the bayou's flow to be 80 percent sewage. In 1967, Dr. Joseph L. Melnick of the Baylor University Medical School examined the bayou's water in downtown Houston—long before it reached the ship channel area—and found what he calculated to be enough viruses to infect 77 million persons per hour. "It's just plain sewer water," Dr. Melnick, a virology expert, said. "You shouldn't bathe in this water. You shouldn't even get it on your skin. You shouldn't have anything to do with it." Four years later—in June 1971—two of Houston's sewage plants were discharging 103 million gallons of unchlorinated waste into Buffalo Bayou each day.

Galveston Bay, of course, is paying the price of such wanton pollution. A large part of the estuary has been closed to shellfish harvesting because of the bacterial pollution from raw and unchlorinated sewage. Fish kills attributable to both urban and industrial pollution are common. Fish deformities are becoming more apparent. And the bay—the prime recreation center for Houstonians for many years—now is shunned as unfit for swimming, fishing, and other water pleasures. The bayshore, once lined with piers and boat stalls, has little more than a scattering of battered posts sticking from its discolored waters as reminders of happier days.

The prospects of bringing Galveston Bay back to a healthy condition are, at best, poor. The Trinity River canal project still hangs around, threatening the bay's most significant source of freshwater and hazarding, by inundation, prime estuarine marshlands. Thermal pollution—the tampering with water temperature in the bay—is being posed by electric generating plants. A proposed dyke-and-levee system threatens tidal flow from the gulf. But while the prospects of making Galveston Bay a recoverable resource fade, there is grassroots reaction in Houston, at Wallisville, and, especially significantly, at Corpus Christi.

Before it reaches sewage stations and the long chain of industrial waste outlets, Buffalo Bayou meanders through ritzy River Oaks, a residential area ranking with the finest anywhere in the United States.

The benign little bayou forms part of the setting—and its value in its natural state is recognized by wealthy homeowners as well as public-interest conservationists. In 1971, a plan was developed to straighten the bayou channel in the name of flood control. Thus was born The Bayou Preservation Association, an alliance of property owners and environmentalists who mounted a full-scale opposition program and went public. The flood control project was stopped, and, perhaps most significant of all, the Association gathered the support of the Harris

County Soil and Water Conservation District, the Flood and Drainage Committee of the Houston Chamber of Commerce, and the Houston Builders Association in seeking an officially acceptable comprehensive plan for flood-plain management in the Houston area.

The achievement, in itself, was modest, and, for many of those involved, it was self-serving. But it was a forward step in coping with the Buffalo Bayou problem—a foot-in-the-door move toward bigger things in the somewhat belated effort to attach value to the quality of a clean stream and a healthy estuary.

An attempt to stop construction and operation of the Wallisville Dam on the lower reaches of the Trinity River still hangs in legal limbo, but the mere fact that such a step was taken and was treated with credence in the courts is noteworthy.

The Wallisville project, which would dam the Trinity at a point where the river flows into that part of Galveston Bay known as Trinity Bay, would create a shallow lake over nearly 13,000 acres of marine nursery grounds. While it would stop the movement of salt water up the Trinity channel, it also would adversely affect the flow of freshwater into the bay.

The suit was brought by two individuals joined by various environmental groups, including the Houston Sportsmen's Club, the Texas Shrimp Association, the Environmental Protection Fund, the Houston Audubon Society, and both the national organization and the Houston Chapter of the Sierra Club. The suit is based on the premise that the Wallisville project is related, in its implications, to the channelization of the Trinity to Dallas—and that the environmental implications of such wholesale tampering with one of Texas' more significant streams have not been fully assessed. Win or lose, the Wallisville Dam foes are sure to give heart to others who would undertake other fights to halt assaults on Texas estuaries. They already have—as is evidenced in the pitched battle to stop the construction of a superport at Harbor Island, a marshy triangle of land inside the Texas island chain near Corpus Christi.

THE HARBOR ISLAND BATTLE

Harbor Isand is located just inside San Jose and Mustang islands. The waters which move through Aransas Pass, the inlet from the gulf between San Jose and Mustang, break against the eastern point of Harbor Island and surge along its sides and through a shallow channel in its center into a system of 11 bays that form the shoreline of the southern half of the Texas coast.

The gulf waters surging along the south side of Harbor Island move into Corpus Christi Bay, then into Nueces Bay, Laguna Madre, and Baffin Bay. The Nueces River system and a variety of smaller streams match the flow from the mainland. The seawater flow through Harbor Island nourishes Redfish Bay. Along Harbor Island's north side, the Lydia Ann Channel carries water from the gulf to Aransas, Copano, Port, St. Charles, San Antonio, and Hynes bays. The estuarine balance in the latter bays is maintained by the flow of the Guadalupe-San Antonio river system and the lesser Aransas and Mission rivers.

There already is a deepwater channel from the gulf through the San Jose-Mustang inlet. It courses south of Harbor Island across Corpus Christi Bay to the Corpus Christi metropolitan area. A fork of the channel—also deep enough to accommodate ocean-going vessels—attaches itself to the industrialized north shore of Corpus Christi Bay for a short distance.

The Harbor Island superport would provide dockage for medium-sized VLCCs—the so-called supertankers designed to carry million-barrel crude oil cargoes from distant ports. The superport plan is sponsored by the Nueces County Navigation District No. 1 and enjoys the support of most of the community's powerful industrial interests and certain vocal segments of the Corpus Christi business establishment. To construct such a facility would necessitate substantial widening of the San Jose-Mustang inlet, fashioning of a super turning basin where inflow waters make their three-way separation into the various bays, cutting of berthing space into Harbor Island, relocating of the shallow channel through Harbor Island to Redfish Bay, and dredging of the inlet, turning basin area, and berthing area to a water depth of more than 72 feet.

The proposed superport provoked what The Corpus Christi Caller described as "The Battle of Harbor Island, 1973 Style." The Coastal Bend Conservation Association assumed the lead role, supported by the San Antonio-based Committee to Save Our Texas Beaches and Bays. The opposition began forming in mid-August, 1973. The showdown dates were September 19–20—the appointed time for a public hearing before the U.S. Engineers in Corpus Christi.

The results of the hearing were not conclusive, of course. But the month-long effort by conservationists to muster and consolidate public support added a blueprint for future action by environmentalists.

The superport opponents began with a sound basis for opposition. There was a plausible alternative: the monobuoy. A monobuoy system would provide for the unloading of the big tankers far out in the gulf through the use of hoses attached at the water surface to floating buoys and at the gulf floor to underground pipelines leading to shore. Monobuoys would eliminate the need for an onshore port—and they could be expected to be more than theoretically effective. More than 100 monobuoy systems are in use around the world. Some have been in use since 1959.

Furthermore, it turned out, the monobuoy system had strong support and the dredging approach had outspoken critics in official circles. No less an authority than the U.S. Corps of Engineers—the agency holding the hearing—had expressed itself this way in a June 1973, report entitled "Report on Gulf Coast Deepwater Port Facilities in Texas, Louisiana, Mississippi, Alabama, and Florida': Of the three facility systems investigated—dredged channels, artificial islands, and monobuoys—the monobuoy system is the most economically and environmentally feasible."

Speaking specifically of the Texas Coastal Bend—the area centered around Harbor Island—the Corps added: "This zone supports active commercial and sport fisheries and represents a significant recreational region whose utility could be diminished by a deep port development in the area . . ."

A report entitled "Environmental Aspects of a Supertanker Port on the Texas Gulf Coast," published in December 1972, by Texas A & M University, contained this statement:

> In addition to the first cost aspects of channel deepening, other considerations which, when taken in toto, appear to rule out this approach as an alternative to the offshore port, include such things as annual maintenance costs and environmental impacts other than those associated with disposal of dredge spoil . . .

The U.S. Army Engineer Institute for Water Resources had retained Robert R. Nathan Associates, Inc., of Washington D.C., to prepare a report entitled "U.S. Deepwater Port Study" in August 1972. The report stated:

> Dredging and spoil disposal for deepwater ports, if resorted to on a massive and extensive scale, could create environmental problems almost equal to those of petroleum spills . . . However, for the most part, offshore facilities requiring limited or no dredging offer an economic, and environmentally less destructive alternative for crude petroleum imports . . .

The Texas Environmental Coalition focused directly on the proposed Harbor Island project with "A Statement Concerning Deepwater Port Location in the Corpus Christi, Texas, Area." The statement was drawn by Espey, Huston, and Associates of Austin, Tex., and contained this comment: "Establishment of a major oil depot with very large tankers coming into the Aransas Pass area will increase the oil pollution because some leakage, spillage, and escape is unavoidable . . ."

One of the strongest statements was found in "Offshore Terminal Systems Concepts," prepared by Soros Associates, Inc., of New York for the U.S. Department of Commerce Maritime Administration. The statement read:

> The traditional coastal port consists of entrance channels, anchorage areas, turning basins, and shoreside terminal berths . . . Many existing port structures would be undermined by further dredging. As bulk carrier depth requirements reach 60 to 100 feet, the practical limitations of the traditional port will have long been exceeded for practically all the existing primary bulk cargo ports, particularly on the Atlantic and Gulf coasts. The problems of turning and handling these large vessels within the traditional port confines will become dangerous even if dredged channels and basins could otherwise handle the deep drafts. Dredging beyond 50 feet in depth would be very difficult to justify both economically and environmentally.

The office of the Governor of Texas provided two general comments in "Texas Coastal Resources Management Program," a comprehensive report to Interagency Council on Natural Resources and the Environment. The comments:

> Bays and estuarine areas are irreplaceable resources essential to more than 70 percent of all marine organisms . . .
>
> . . . it is recommended that the State of Texas and its citizens . . . prohibit the sale or lease of State-owned wetlands for development except where essential to fulfill some definite human need and where no feasible alternative exists.

Thus armed with significant opinion, the Harbor Island superport opponents put their position to a public test. On Labor Day weekend, circulars entitled "Save Our Beaches, Save Our Bays" were passed out to motorists pulled to a stop on Harbor Island to await ferry movement to the Mustang Island community of Port Aransas. The circulars explained that a plan was afoot to build a superport on Harbor Island, then added:

> A superport on Harbor Island would require a channel almost three times as wide and nearly twice as deep as the present inlet from the Gulf of Mexico.
>
> The cost would be enormous. The flood danger from tidal surges, particularly during hurricanes, would constitute a tremendous risk to lives and property. Uncontrolled oil spills could blacken a half-dozen bays, ruin our island beaches, do immeasurable damage to bird and marine life, and destroy a multi-million-dollar tourist and recreation area.

> Don't let anybody fool you—there is no way to control a tidal wave and no fool-proof way to stop the spread of an oil spill.
>
> And don't let anybody tell you that a superport inside the Texas island chain is necessary to support the Texas economy or to provide jobs. It isn't necessary. The U.S. Engineers have made analyses which show that an offshore terminal in the Gulf of Mexico would cost less and accomplish the same purpose.

The message urged anyone interested in stopping the Harbor Island superport project to sign a coupon on the bottom of each circular. The response was tremendous. By the end of the 3-day holiday period, some 4,000 persons had read, signed, and returned the circulars. More than 1,500 other signatures were gathered, mainly in Corpus Christi, prior to the September 19–20 hearing.

A major newspaper advertising campaign was mounted. A dramatic three-color, two-page display featuring a map showing the proposed Harbor Island superport location and projecting the possible consequences of a major oil spill in the port area was the starter. The advertisement was captioned: "Are You Willing to Pay This Price for a Superport on Harbor Island?" The price, of course, was the possible saturation of the bay and estuary areas with crude oil.

The authoritative quotations cited above were put together in a full-page blockbuster with this caption: "Before You Let Anybody Talk You Into Believing the Harbor Island Superport Would Be Good for Corpus Christi and the Texas Coastal Bend, Read These Findings." The advertisement, like the circulars, contained a coupon for opposition signatures.

The next advertisement made it clear that there was an alternative to the Harbor Island superport. The heading stated:

> **Can Corpus Christi Have The Benefits of a Superport Without Jeopardizing Our Beaches and Bays?**
>
> **It Certainly Can—If The Port Is Built in the Gulf Instead of on Harbor Island.**

The pro-monobuoy statements by the U.S. Engineers were prominently displayed.

As the hearing date neared, 10 reasons why the Harbor Island superport should be opposed were offered:

1. The Harbor Island Superport Plan Already Is Obsolete. A superport inside our bay system at Harbor Island, as proposed, would accommodate only medium-sized supertankers. Ships almost twice that large already are under construction and still larger vessels are being planned.

2. The Harbor Island Superport Limits Our Economic Benefits. If the large supertankers can't dock, they can't unload. If they can't unload, we lose economically. An offshore monobuoy system would make possible the discharging of crude oil from supertankers of all sizes.

3. The Harbor Island Superport Has an Unsigned Price Tag. If a 72-foot channel can be dredged, will we then be asked to dig it deeper for bigger ships? How will the channel be maintained? What will be the final cost? Who'll pay the bill? Why haven't these questions been answered?

4. Harbor Island Will Put Us Behind in the Superport Race. The construction of an inland superport is a mammoth, slow process. The Caller-Times of August 26, 1973 stated that officials have estimated results of the Harbor Island feasibility study "may not be available for up to three years." Construction then could require an even longer period of time, pushing the completion date to 1979 or later. If the Seadock monobuoy is put into operation up the Texas coast at Freeport in 1976, we could find our area three or more years behind in superport development.

5. Harbor Island Is a Throwback to Isolated Port Planning. The energy crisis is a national concern. So is the docking of supertankers. That's why coastwide port systems have been studied so carefully. The attempt to force isolated consideration of Harbor Island as a superport site is a step backward in port planning.

6. Harbor Island Endangers Our Entire Bay System. The inlet between St. Joseph and Mustang islands is the prime source of fresh seawater for our entire Coastal Bend bay system. The system includes San Antonio, Copano, St. Charles, Aransas, Redfish, Nueces, Corpus Christi, and a dozen smaller bays, plus the Laguna Madre. A superport directly inside the inlet would be a pollution nightmare. It's hard to imagine a more damaging superport site.

7. Imagine the Effects of a Harbor Island Oil Spill! An uncontrolled crude oil spill at a superport on Harbor Island could blacken our beaches and bays, endanger bird and marine life, and destroy a multi-million-dollar tourist and recreation area. Let no one fool you—there is no foolproof way to control a big oil spill.

8. The Harbor Island Superport Is a Multi-Danger Plan. The danger of ship collisions and groundings hangs over any plan to build an inland superport. An explosion could turn a supership loaded with crude oil or liquified gas into a gigantic floating

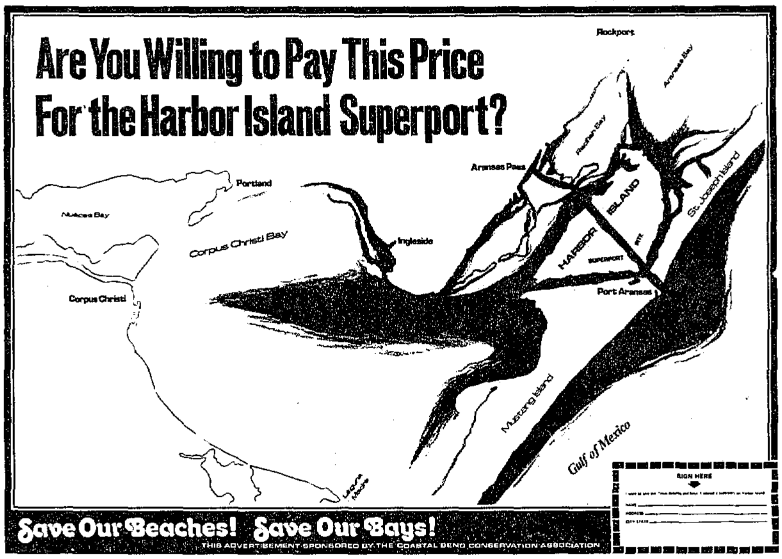
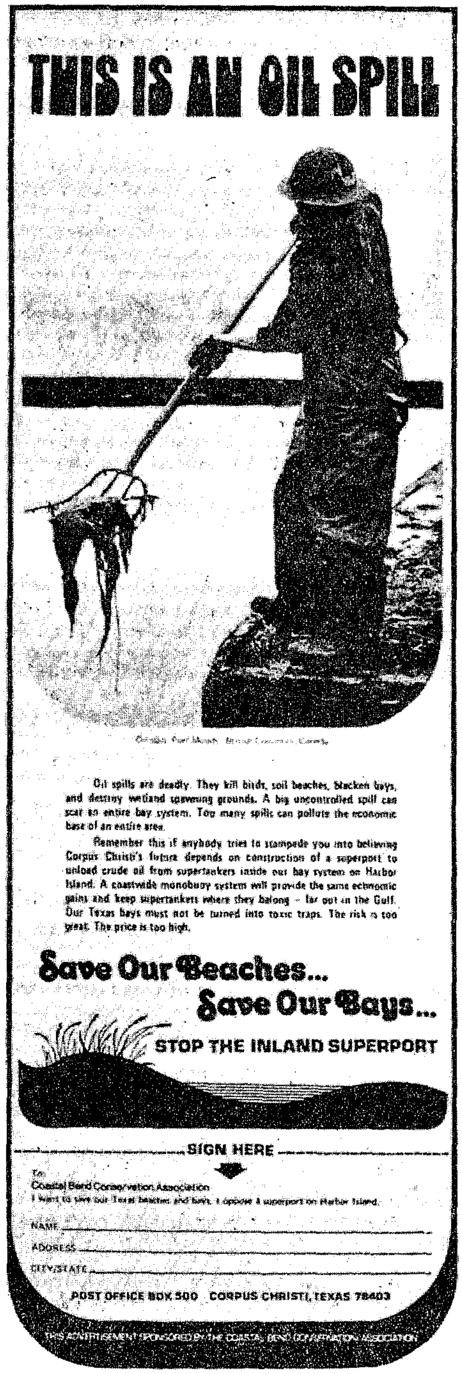


ILLUSTRATION 1



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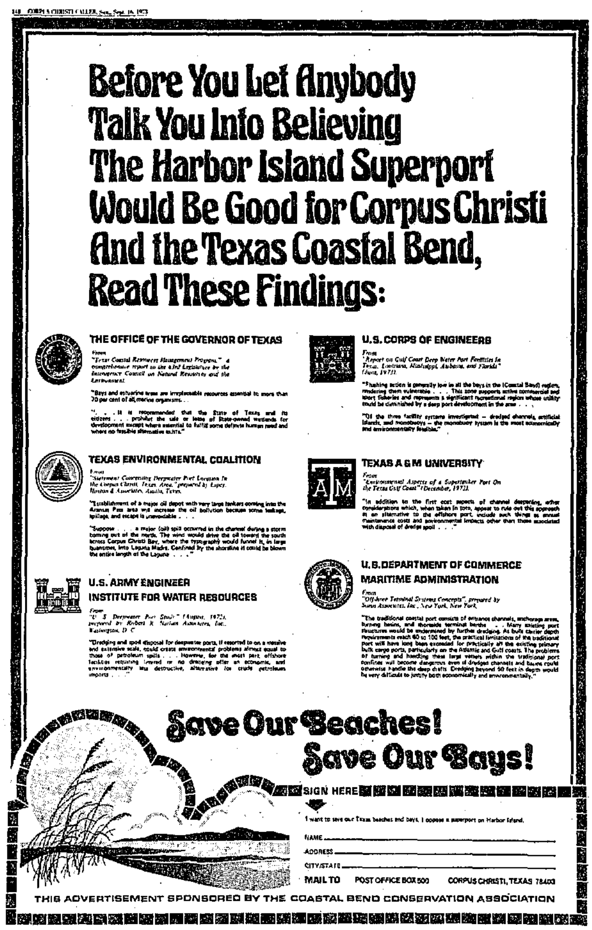

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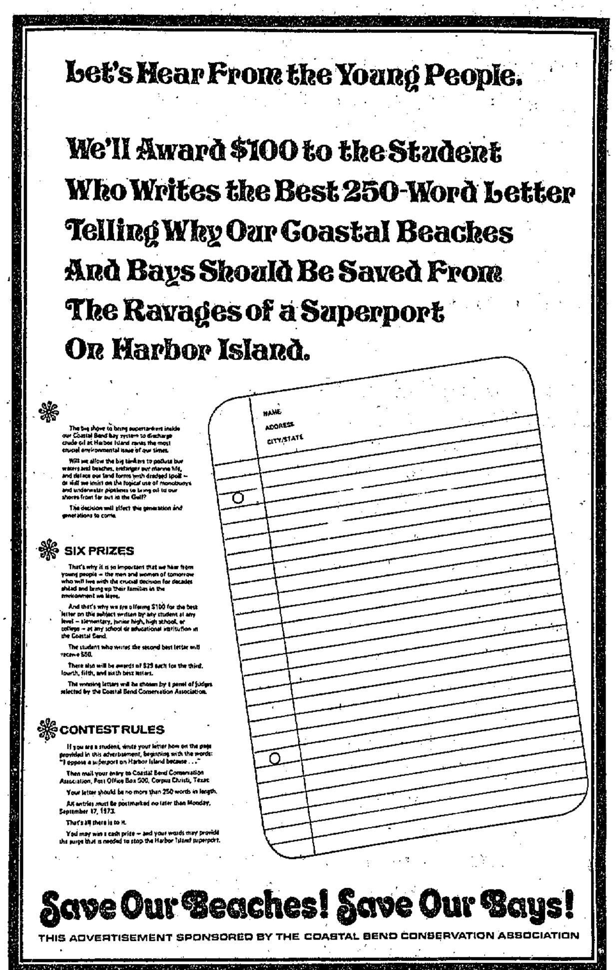

ILLUSTRATION 4

bomb. There also is a real danger to life and property from tidal surges caused by channel widening and deepening to accommodate supertankers.

9. Harbor Island Will Blight Our Existing Economy. A superport inside our coastal islands will deface landforms with dredged spoil and pollute bay waters. It is bound to strike a solid blow to sport fishing, commercial fishing, bird life, tourism, and our own enjoyment of our environment. The cost in dollars will run into millions. The cost that can't be measured in dollars will be staggering.

10. All Major Studies Favor Offshore Superport Plans. The only thing new about superport planning is the high-pressure attempt to force the building of a superport on Harbor Island. Major studies conducted by and for federal and state agencies concerned with superport development favor offshore ports far out in the gulf.

The 10-point broadside was contained in a full-page newspaper advertisement with these instructions:

> **Here's What You Can Do To Stop the Harbor Island Superport—**
>
> **Go to the U.S. Engineers' hearing at 6:30 p.m. Thursday at Roy Miller High School Auditorium . . .**
>
> **Speak out at the hearing to save our beaches and bays by keeping the superport outside our Coastal Bend bay system.**

An advertisement—also displayed on a full-page scale—urged: "Let's Hear From the Young People." It offered, in the name of the Coastal Bend Conservation Association, a prize of $100 to the student writing the best 250-word letter "telling why our coastal beaches and bays should be saved from the ravages of a superport on Harbor Island." There was a second-place prize of $50 and four other prizes of $25 each. The contest was open to any student at any level—elementary, junior high, high school, or college—at any school or educational institution in the Corpus Christi area.

Each letter had to begin with the words: "I oppose a superport on Harbor Island because . . ." There were more than 100 responses.

As the hearing approached, The Corpus Christi Caller summarized the situation in a lengthy article published September 16. The article listed the pros and cons of the Harbor Island superport as follows:

> PROS:
>
> Economic boost.
> Bring in new industry.
> Decrease ship numbers (not tonnage).
> Channel will stabilize bay system.
> Help ease fuel crisis.
>
> CONS:
>
> Destroy fish, shrimp and crab nursery grounds.
> Dredging and spoil disposal harm.
> Oil spill danger.
> Increased flood threat from hurricanes.
> Expense of channel maintenance.
> Demand on land, water, air resources from secondary development.

Port officials, the article stated, claim "the economical advantages of a landlocked inshore port situated inside the Aransas Pass Bar far offset any possible ecological or environmental damage that might occur to the Corpus Christi Bay area."

But, the article added, "environmentalists maintain that construction of the port in estuarine areas will destroy valuable marine nursery grounds which are important for the preservation of gulf fisheries. They also argue that port development will inevitably lead to further industrialization that would decrease the quality of the area's environment."

The article, in its own right, pointed out that "more than 3,000 acres of land are estimated to be needed for facility construction. Much of this land is shallow and vegetated, functioning as nursery and feeding grounds for marine organisms and birds. Ninety-five percent of commercial fish species are said to be dependent on estuarine areas." It also cited the fact that Ernest Simmons, coastal fisheries supervisor for the Texas Parks and Wildlife Department, pointed out that construction of the deepwater port would immediately destroy many acres of prime spawning and nursery grounds for sea trout, redfish, flounder, blue crabs, and shrimp. "The deepwater port would thus affect adversely a multimillion dollar fishing industry. We would also lose feeding grounds for waterfowl and other birds," Simmons was quoted as saying.

Rudy Martinez, a biologist with Parks and Wildlife, and John G. Degani, field supervisor with the Division of River Basin Studies in the U.S. Bureau of Sports Fisheries and Wildlife, concurred with Simmons in print. Martinez was quoted as saying: "We are slowly losing our nursery grounds in this bay system as industry is coming in and people are building. The Harbor Island development would cut down on the amount of nursery grounds available for organisms." Most marine life spends some part of its life cycle in these areas, Martinez added.

Dr. Henry Hildebrand, of the Department of Biology at Texas A & I University-Kingsville, claimed publicly that the tremendous amount of spoil created by the dredging activities would keep the water turbid for months. "The fine clay sediments would create a turbidity off Port Aransas which would have serious impact on sports fishery. The fisherman will have to go much farther out to find the fish," the biologist said. Hildebrand said that besides the initial turbidity caused by the dredging, runoff from spoil disposal areas would have adverse consequences. "Draining from disposal areas of the colloidal clay sediments which would be dredged up could adversely affect the organisms in Redfish Bay and possibly cover up the grass-flats," he stated.

Hildebrand also commented that the 72-foot channel would profoundly affect the bay production of fish. The Aransas Pass Channel is a bottleneck for migrations in and out of the bays, he said, and thus the most sensitive area in the coastal system. "Little shrimp use certain clues to enter the estuaries from the gulf. Tidal and salinity changes resulting from a deeper channel would affect the migration pattern," he warned.

Dr. Charles Holmes of the Office of Marine Geology, U.S. Geological Survey, said: "The feeling among geologists is that the channel will fill in, but at a rate not known. The question should be investigated."

The hearing before the U.S. Corps of Engineers opened before a full house. The Miller High School Auditorium was packed—both the main level and the balcony. In the lobby, environmentalists passed out "Save Our Beaches, Save Our Bays" bumper stickers. Outside, a king-sized billboard trailer attached to an automobile carried an easily understood message. It stated: "Stop the Superport."

Edward C. Fritz of Dallas, chairman of the Texas Committee on Natural Resources and a leader in the Wallisville battle, testified: "The development plan for a multi-purpose deep draft inshore port near Port Aransas as presented by the Nueces County Navigation District is environmentally unsound. To construct the necessary deep draft access channels alone could seriously alter the balance of nature in the area. Any ecological modifications necessary to build and maintain a superport complex would have a serious and far reaching impact on the biosphere of an area. This particular plan threatens to wreak total havoc on the especially delicate and complex natural interrelationships in the Port Aransas region. Thus serious consideration should be given to the denial of a permit for this scheme. Indeed, serious consideration needs to be given to the question of whether or not any superport ought to be constructed at all in the Corpus area. One for Texas should be sufficient, and there are other areas with greater advantages to Texas and the nation."

Jake Powers, a petroleum consultant, told the gathering: "The Nueces County area is indeed fortunate in having a majority of its income derived from the petroleum industry . . . In fact many of us depend on petroleum in one facet or another as our basic income. We look forward to additional oil and the income it might bring. We do, however, feel like a superport would not benefit this area as well as an offshore terminal or monobuoy plan."

Yancey White—an attorney who is a graduate of the United States Merchant Marine Academy, a veteran of the United States Navy, and a former ship's officer in the United States Merchant Marine—pointed out that the secondary purpose of the proposed Harbor Island superport was to load bulk carriers with grain for foreign shipment. "The hard evidence does not support the proposition that a bulk loading facility for grain at Harbor Island would be of any substantial benefit to the Port of Corpus Christi," White testified. "The reasons are simple and capable of factual support. The principal reason is that many of the countries purchasing our grain have severe draft limitations which restrict the size of the vessel that can enter the harbor for alongside discharge. To be specific, India, one of the primary purchasers of American grain, has severe draft limitations and cannot accept today vessels with 40-foot drafts which Corpus Christi is capable of loading. The maximum draft for which a vessel can enter a harbor in Venezuela is 34 feet. The maximum draft for alongside discharging in Mexico is approximately 30 . . . Stated in simple terms, it is futile to load a bulk carrier with grain to a 70-foot draft when the port of discharge can only accommodate a vessel of 30 feet. This is true because many, if not the majority, of the grain importing countries are underdeveloped nations and thus do not have adequate port facilities to receive large bulk carriers."

The chairman of the Corpus Christi Chamber of Commerce's Superport Committee was Edward H. Harte, publisher of The Corpus Christi Caller-Times. Later, in an editorial column, Harte gave his appraisal of what happened at the hearing at Miller High School. The Harbor Island superport project, Harte wrote, took a "terrible drubbing."

After the hearing, the environmentalists had the final words. In another double-page, three-color newspaper advertisement, they offered the public a sketch of a serene Harbor Island setting with this text:

> **Harbor Island . . . it's one of the Coastal Bend's great natural resources.**
>
> **Around it flow the fresh seawaters which enter our island chain to feed our entire bay system from the Aransas National Wildlife Refuge at Austwell to the lower reaches of Laguna Madre. Its wetlands nurture our very existence, providing spawning beds for marine life and a nesting ground and natural habitat for countless species of birds. Along its sub-sea-level fringe is Texas' only mangrove swamp. Its delicate dunes have fashioned the contours of history.**
>
> **There are some natural resources which must be sacrificed to that human on-rush known as progress.**
>
> **This one must not be.**
>
> **The unnecessary dredging of a deep-draft superport on Harbor Island for the unloading of crude oil from supertankers will deface the island itself, pollute our bays, endanger our commercial and sports fishing, and destroy our recreational and tourist attractions.**
>
> **The public hearing held last week before the U.S. Corps of Engineers in Corpus Christi made it abundantly clear that the people of the Coastal Bend and those who share our concern about the well-being of the Texas shoreline want supertankers kept and unloaded where supertankers belong—in the deep waters of the gulf.**
>
> **As one speaker pointed out, there is no last-gasp need for an inland superport on Harbor Island. To suggest that an inland superport is the only answer is to ignore the economy and efficiency of the offshore monobuoy unloading system.**
>
> **Yes, the people spoke—not simply from the podium but by their presence. More than 700 persons attended the hearing. Nearly 6,000 others—enough to fill the Miller High School auditorium almost six times—sent their expressions in opposition to the superport in writing.**
>
> **Harbor Island is a great natural resource—but it is even more.**
>
> **It is the key to maintaining and improving the quality of life in the Coastal Bend.**
>
> **It must not be sacrificed.**
>
> **And it won't be.**

The Harbor Island superport proposal has had rough seas ever since the September 1973, public hearing. In March 1974, Bechtel, Inc., a consulting engineering firm, put a $260 million price tag on the project. That is far more than the original estimates of less than $100 million. The $260 million cost, Bechtel pointed out, is based on a start of construction within 13 months. A start, as of this writing, is not in sight.

Perhaps the most significant factor for environmentalists is Bechtel's open reference to the project as Phase 1. What are the other phases? Where does the superport project lead? What is the full scope of potential estuarine destruction? In view of the Wallisville Dam litigation, these questions become especially relevant.

Untimely oil spills in the South Texas bay system related to the Mustang-San Jose inlet also have drawn attention to the hazards posed by the project. An oil spill closed the Port of Corpus Christi for two days. Almost a week was required to clear the channel of the 6,000-barrel spill. A smaller spill in San Antonio Bay, near the nesting grounds of the nearly-extinct whooping cranes, also attracted public attention.

Exxon, one of the industrial giants advocating the Harbor Island superport, came across its own tracks with a national magazine advertisement headed: "Offshore Oil Terminals. A safer, more economical way to get millions of barrels of oil from ship to shore to you."

An awareness of the value of Texas estuaries is growing. The importance of the role of the public in Texas estuary protection is undeniable. The blueprints have been drawn. The battle has been joined. And, for the first time, a genuine appreciation of the Texas coast seems near.

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THE ROLE OF CITIZEN ACTION GROUPS IN PROTECTING AND RESTORING WETLANDS IN CALIFORNIA

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ABSTRACT

The shocking destruction by man of California's wetland and coastal resources has occurred for more than a century, by competing uses for industrial, commercial, residential and recreational purposes. More than 80 percent of California's 21 million people live within one-half hour's drive of the coast. Pressures on resources in coastal areas is unbearable. This paper tells what citizen action groups have done in attempting to reverse these trends.

INTRODUCTION

Citizen action efforts in wetland and coastline protection in California, although of recent origin, are illustrative of some of the most dramatic and most productive results in the nation.

For more than a century following California's admission to the Union in 1850, it was common and accepted practice to misuse the coastline and to destroy the wetlands. Since 1900, 90 percent of the fertile and productive marshes, lagoons and sloughs in southern California have been diked, drained, polluted, filled, or dredged to make way for freeways, shopping centers, subdivisions, industries, condominiums, and marinas. Of the 381,000 acres of coastal wetlands existing in all of California 75 years ago, only 125,000 acres remain today.

Citizen action groups, tired of witnessing the slow but certain destruction of coastal shoreline waters and wetland habitat, decided to call a halt to such activities. Effective efforts of citizen groups in California have sometimes been on the local level and other times statewide. The methods used varied considerably.

Hopefully, the California illustrations cited will be beneficial to other citizen groups in the nationwide effort to save decreasing coastal wetlands from further destruction.

CARMEL RIVER BEACH AND UPLAND ARTICHOKE FIELDS

Saving threatened wetlands from destruction by fund raising for public purchase presents problems in that the amount of money needed is difficult to raise during the time available before the destructive action occurs, and should the purchase be successful who is to administer the wetland?

The saving of the Carmel River Beach, lagoon, and wildlife refuge from high density development was done by separate but interdependent citizen action groups—one concerned itself primarily with public education and fund raising, while the other carried on the political action.

Shortly after World War II the Carmel River Beach, with its unsurpassed view of Point Lobos, was up for grabs. Adjacent to the beach was a beautiful 27-acre lagoon, providing habitat for the brown pelican, blue heron, and many other species, some rare and endangered. Constant filling to make room for new homes in a nearby subdivision threatened the lagoon's very existence.

Determined to save this beach and wetland from development, Carmel citizens turned in 1950 to their Point Lobos League, a non-profit organization, whose purpose was to preserve natural, scenic and recreational areas for use and enjoyment by all of the people. Margaret Owings of the league solicited the aid of her friend, Newton B. Drury, chief of California's State Division of Beaches and Parks, who said of this effort, "No scenic and recreational resource in the United States is more sorely in need of preservation."[1] However, Drury, former director of National Park Service, was helpless under California law to purchase the Carmel River Beach and lagoon without local matching funds. With Drury's support, Francis Whitaker, the Point Lobos League's

[1] The Living Wilderness—Sumer, 1950, p. 17

president (who was also Carmel's blacksmith), gathered artists, lawyers, doctors, journalists, retired military, and conservationists to his Forge in the Forest, where a campaign for vigorous fund raising was launched and a goal of $25,000 set. The league's efforts resulted in local artists donating 125 excellent paintings. Auctions and other money raisers produced $15,000 in donations to save the beach and lagoon. Of this effort, a well known journalist wrote,

> Contributions have been in the best conservation tradition, from small donors. These are the people from all over the United States—as well as little Carmel—who have known the sweeping curve of the beach with its yellow-white sand against the blue-green lagoon at the Carmel River mouth under the wild Santa Lucia Mountains![2]

Following the league's successful fund raising, the first breakthrough came when the state was able to acquire the 27-acre lagoon for a wildlife refuge. Pushed by the Point Lobos League, Monterey County made available to the state $25,000 in funds which it had earmarked for parks and beaches elsewhere in the county. The people of Carmel having done their part, the state then proceeded in 1954 to acquire an adjacent 80-acre beach and bluff, thus creating the Carmel River Beach and Wildlife Preserve.

To the east of the beach and wildlife refuge lies the 292-acre Odello artichoke fields that straddle Highway 1. For 47 years the Odello family had farmed these lands, but in 1971 they felt that the time had come to sell. Proposed was a $60 million development including 944 dwelling units, a 600-room hotel and a 300-acre spa to be located next to the wildlife refuge. Rezoning by the county would be required to make the project possible.

Worried about population increases, in that the proposed development would house more people than lived in Carmel, citizens again organized to save their environment. Traffic congestion, smog, tax burdens, damage to the state beach and wildlife refuge, and flooding of the Carmel River were all of great concern to the people. At first the controversy was fought solely on the political front. From the beginning there was widespread community feeling that the Odello family should be allowed to develop their lands as had others before them. Also, strong was support for purchase of the land for public open space preservation. To meet the developer's challenge, two organizations were formed. Each acted separately but of necessity depended upon one another if the land were to be saved. One organization known as the Carmel Area Coalition, together with other conservation groups, carried on the necessary political activity before the county planning commission and board of supervisors. The other organization, OLAF (Odello Land Acquisition Fund) was an IRS tax approved nonprofit corporation which confined its activities to fund raising. The landowners and developers were pushing for rapid approval of the plan and rezoning of the property. The coalition was strongly resisting this effort, thus hoping to buy time while OLAF was pursuing the herculean task of raising the money to purchase the land from the disinterested landowners at a then unknown price. Once the land was rezoned, the new inflated value caused by rezoning would put the price out of reach for public acquisition.

From February 1971 until the late spring of 1974 the battle to save the land continued. Prudential Life Insurance Company policy holders on the Monterey Peninsula and elsewhere were disturbed that their company was the financial backer of the plan. In May 1971 the company withdrew financial support and immediately thereafter the landowners indicated an interest in selling the westerly half of their property to OLAF, but only after rezoning was approved.

By June 1971 OLAF, backed by a $50,000 pledge from the city of Carmel, had raised $200,000 in cash and pledges and was trying to interest the State of California in acquiring the western half of the land to protect the state river beach and wildlife refuge. In July 1972 the planning commission, at a packed meeting, voted 6–2 to approve the development and in October, with growing support for public acquisition, the Monterey County Board of Supervisors reversed the planning commission in a 3–2 vote but without prejudice, meaning that the developers were free to re-apply.

The efforts of the coalition and conservation organizations were gaining increased support locally and throughout the state, and OLAF's fund raising efforts were truly amazing. Contributions flowed in from as far away as Hong Kong, Venezuela, and Washington, D.C. One social security recipient donated, and urged others who could afford it to contribute the small increase allowed in social security benefits! An 11-year-old boy on a street corner collected $105 in three hours time for OLAF. A wealthy woman gave a $30,000 Pebble Beach lot, and a druggist offered $.05 per bottle for the return of used pill bottles, receiving 4,080 pill bottles and sending a check for $108. The city of Carmel's pledge for $50,000 was later increased to $100,000.

High school students made door-to-door campaigns, and an ecumenical church service on the

[2] Robert E. Brunn, Carmel takes steps to save famed river beach. The Christian Science Monitor, June 13, 1950.

banks of the Carmel River gained more support; soon the national and east coast media with NBC, CBS, New York Times, National Observer, The Washington Post, and Halifax Nova Scotia Herald, as well as the National Geographic Magazine, all became interested in Carmel's trying to save its open space.

The State of California appraised the westerly 155 acres of the land at $1,750,000, and the Odellos agreed to accept this amount, but the state was only willing to provide one-half the cost.

Responding to the efforts of the coalition and OLAF, the county board of supervisors under the leadership of Willard Branson, its chairman, tried to form itself into a redevelopment agency to help obtain the matching funds, using tax increment bonds. Complicated political and legal problems caused the redevelopment idea to be abandoned. Then local assemblyman Bob Wood won legislative approval authorizing the purchase of the artichoke fields as an adjunct to the Carmel River State Beach. With the $100,000 pledge from the city of Carmel and the $250,000 raised by OLAF, and reduction by $100,000 in the landowners' selling price, the state furnished the balance and the sale was completed.

Thus, the westerly 155 acres of this land adjoining the wildlife refuge were forever preserved as a part of California's Carmel River Beach State Park and Wildlife Refuge, and efforts are still continuing to save the easterly one-half of the Odello land for open space.

Happily, the state leased the lands back to the Odellos, and green artichokes, interspersed with yellow mustard, still dominate the flatland next to the Carmel River Beach, lagoon and wildlife refuge across the bay from Point Lobos.

UPPER NEWPORT BAY

A 55-year struggle to preserve one of the last remaining wetlands in southern California culminated in a victory for conservationists when it was announced in mid-November of 1974 that the State Department of Fish and Game would supervise in Upper Newport Bay, Orange County, a 741-acre ecological preserve, the largest in the state.

Upper Newport Bay is located 26 miles south of Los Angeles and more than 80 million people, or one-half of the population of California, live within its 80-mile radius. The 3½ mile long Upper Bay, with its 1,000 acres of relatively undisturbed wetlands, provides a most important habitat for no less than five state and federally recognized species of endangered birds as well as important varieties of fish and plant life.

The saving of this important land and water from certain destruction of its natural resources is a lesson in community mobilization, effective public education, successful litigation, and determined citizen followthrough.

Prior to 1901 all tidelands in the Newport Bay area were held in trust by the State of California. In 1901 the state sold 273 acres of tidelands to James Irvine, the predecessor of the Irvine Company which is today the largest landowner in southern California. In 1919 the state granted to Orange County, in trust, other tidal and submerged lands for the development of a harbor in the Upper Bay.

As the result of litigation in 1926 between Orange County and the Irvine Company, Irvine was adjudged to be the owner of the lands above mean high tide, including three small islands whose ownership by Irvine blocked effective use of the bay for Orange County's proposed harbor development. In addition, precipitous bluffs owned by Irvine surrounded much of the bay, thus making access to the water difficult. Irvine wanted to develop its upland properties and obtain access to the bay, and Orange County desired to develop the harbor under its tidelands' grant. Consequently, a plan was evolved under which a land exchange would be made. It would permit Orange County to develop the harbor, a marine stadium, and certain parks in return for Irvine's owning and developing the contiguous lands for low and medium density housing and for aquatic commercial uses. The proposed land swap was approved by the 1957 legislature subject to approval of the State Lands Commission. In 1966 the State Lands Commission withheld its approval on the grounds that the project would create commercial areas completely privately controlled and add to the preponderant private domination of the bay. The following year, however, under a new administration in Sacramento the Lands Commission reversed itself and approved the exchange.

Following such approval, a group known as the Friends of Upper Newport Bay was organized. It feared the exchange would result in both loss of shoreline to the public as well as loss of important wildlife habitat.

The Friends faced an uphill struggle in that the harbor district, the board of supervisors, the State Lands Commission and the state legislature had all given the necessary approval. All that appeared to remain for final clearance was court sanction of the land exchange and a dredging and filling agreement. This would be accomplished by a so-called "friendly lawsuit" filed in 1969 in the Orange County Superior

Court. What was to be a noncontroversial matter became a hotly contested adversary proceeding culminating in a significant appellate court decision of major importance in tideland litigation, and a splendid victory for Friends of Upper Newport Bay.

Joining the Friends of Upper Newport Bay in 1969 was an organization known as Orange County Foundation for Preservation of Public Property. The foundation assisted in the appeal of the trial court's judgment approving the land exchange. Due to the vehement opposition of the Friends of Upper Newport Bay, several most important events took place between the filing of the action and the trial court's decision. The Orange County Grand Jury had passed a resolution questioning the advisability of the exchange and the board of supervisors underwent a change of membership. The new board expressed a desire to rescind the exchange agreement as not being in the public interest and filed an appeal of the decision approving the exchange. Six citizens intervened in the county's appeal, contending that the exchange would result in Irvine's owning almost seven miles of prime waterfront along newly created harbor lines while providing only three miles or less of marginal waterfront property for the public. They were assisted by attorney Phillip S. Berry, former Sierra Club president, and Herman F. Selvin, former president of the state bar, represented Orange County in the appeal.

In February 1973 the court of appeal reversed the trial court's approval of the exchange after carefully reviewing California's tidelands trust. The court included in its grounds for reversal the fact that "... Orange County presently owned and controlled the entire shoreline of the bay area and that as a result of the exchange, it would be relinquishing two-thirds of that shoreline to be conveyed into private ownership."[3]

This decision was the turning point in the determined struggle to save Upper Newport Bay. Irvine as a result of the decision agreed to negotiate the sale of its wetlands long sought by conservation groups for a wildlife refuge. Backed by Friends of Upper Newport Bay and many other Orange County citizens, the State Department of Fish and Game negotiated the sale of 527 potentially highly developable acres from Irvine to the state for $3.48 million. Two hundred seventeen acres of tidelands held by Orange County were then added to complete the 744-acre wetlands preserve.

Credit for preserving what is today California's largest wetland ecological reserve goes primarily to the 100 dedicated citizen members of the Friends of Upper Newport Bay who gave directly of their time, talent, and money. Not only did they carry on an extensive campaign in educating public officials at the local, county, state and federal levels, but they also conducted public tours of Upper Newport Bay for some 15,000 people in addition to special tours for approximately 10,000 students. Working with the Orange County Foundation for Preservation of Public Property, the Friends were able to raise $80,000 for legal expenses to assist in the appeal. In addition, the Sierra Club and the citizen intervenors in the lawsuit played important roles in helping save Upper Newport Bay.

While the Upper Bay's major hurdle, that of public ownership, is resolved, there are still problems in achieving full utilization and restoration of the bay for wildlife preservation and for public enjoyment. The waters of the Upper Bay are threatened by storm drainage runoff from the massive adjacent urban population. Federal assistance to California and the Orange County communities encompassing the bay would help immeasurably to prevent such drainage pollution. It is also essential to protect the bluff land surrounding the Upper Bay from destructive development. To complete the task of protecting Upper Newport Bay, the citizen groups will continue to work until their goal is finally accomplished.

ELKHORN SLOUGH

One of the largest, most important wetlands remaining in California was saved from a major oil refinery being located near its shores—not on the issue of saving the wetland, but rather by citizen action groups interested in clean air.

Elkhorn Slough at Moss Landing in Monterey County, the second largest salt marsh in California, lies about 100 miles south of San Francisco on the edge of the Monterey Bay. During the bird migration in the fall and early spring, its 7-mile slough and 1,430-acre Salicornia Marsh attract over 90 species of birds, some rare and endangered, in addition to a variety of fish, clams, oysters and barnacles.

The biggest threat to Elkhorn Slough came in 1965 when Humble Oil, then the nation's largest marketer of petroleum products, announced plans to construct a $70 million refinery at Moss Landing.

Humble Oil, backed by the Salinas Chamber of Commerce, the Moss Landing Harbor District, and the Salinas Californian, one of the two daily newspapers in the county, proclaimed that Monterey County needed Humble Oil's refinery to provide a permanent labor force of 250–300 employees, plus 1,500 to 2,000 construction jobs and $1,300,000 in new tax revenues for the county. The proposed

[3] *Orange County vs. Heim* 30 C.A.3d 694 at p. 695.

450-acre refinery site was already zoned for heavy industry, with both Kaiser's Dolomite Processing Plant and P.G.&E.'s power plant operating in the area. All that was needed by Humble was a use permit from the county planning commission.

While early in 1965 the county's air pollution control advisory committee recommended the granting of the permit contingent upon meeting all air pollution standards imposed by the county, some 30 miles across the bay downwind from the Humble site, residents of the Monterey Peninsula doubted that a clean, odorless, non-smog producing plant could be built. Prevailing afternoon winds blow from the ocean in the summer months down the long, green Salinas Valley, and there were those who feared that such winds would carry damaging smog into fertile agricultural lands.

To meet the Humble challenge, there was formed on the Monterey Peninsula the Committee on Clean Air. Its president, Charles Kramer of Pebble Beach, a retired business executive, met with the board chairman of Humble Oil, who insisted that there was no air inversion in Monterey County and no danger of smog. Finding talks with Humble Oil officials to be fruitless, Kramer's committee encouraged the formation of a multi-county air pollution control district, and between March and July of 1965, 13,000 residents signed a petition against the proposed refinery. Public opinion was mounting on the Monterey Peninsula against the refinery and other petrochemical industries that might follow. The Monterey Peninsula Herald and its owner, Col. Allan Griffin, were strongly against Humble. This effort was joined by the Sierra Club, Audubon Society, the growers, American Association of University Women, League of Women Voters, and Salinas doctors' wives. Equally strong public opinion and support for Humble's plant were developing among business, labor, and Chamber of Commerce groups in Salinas, the county seat of Monterey County.

The nine member county planning commission's first meeting on the use permit was held early in 1965 and then continued until May. The chief questions it faced were:

1. Could a clean smog-proof refinery be built, and
2. Would there be an influx of associated petrochemical industries once the refinery was approved?

While air pollution consultants urged that an air pollution control district be immediately formed to enforce a strong clean air ordinance, Humble's attorney advised the planning commission that an oil refinery was "one of the most desirable industries that we can attract." A water expert from Humble added that there would be no oil spills from either crude oil or refined products being transported by tankers and barges or being unloaded through submerged marine pipelines. This was before Torrey Canyon.

On July 28, 1965, after a 4-hour hearing ended at midnight, the Monterey County Planning Commission by a 5–4 vote recommended against granting the use permit to Humble Oil. The swing vote was cast by Peter Cailloto, a local hardware merchant, whose business could be jeopardized by his decision, because of the strong support in Salinas for the plant. He nevertheless stated he was worried about air pollution and its damage to agriculture. "One fact is obvious," he said, "you can smell odors from a refinery."

The planning commission's decision was an upset victory for the refinery's opponents; the final decision, however, would be on the appeal to the board of supervisors. As the controversy progressed, Humble inserted large advertisements in the newspapers, urging people to ask their county supervisor to support the refinery.

To counteract Humble's campaign, Dr. Philip A. Leighton of Stanford University, one of the top air pollution experts in the country, pointed out in a series of articles in The Monterey Peninsula Herald how air pollution in other parts of California commenced with reduction of air visibility, followed by plant damage and then by eye irritation. In Monterey County he found that pollution was already at the plant damage threshold and he was particularly concerned with the location of the proposed refinery adjacent to the largest steam generating plant in the nation. When the P.G.&E. plant's expansion was completed, it would produce 2.1 million kilowatts, whose capacity would almost equal the 2.2 million kilowatts of all power plants in Los Angeles County which, when burning both crude oil and natural gas, emitted an average of 150 tons of nitrogen oxides daily. The availability of inexpensive crude oil at the refinery for the steam plant also concerned these experts who summarized their position with these words: "The question of preserving the priceless heritage of clean air versus the broadened tax base and jobs provided by industrialization has been faced by many other communities and resolved in favor of industrialization. These communities are now paying the price in terms of smog."[4]

The county supervisors before making their decision visited Anacortes, Wash., to witness first hand the operation of two refineries in that area.

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[4] The Monterey Peninsula Herald, August 25, 1965, Air Pollution Expert tells of Refinery Peril, Dr. Philip A. Leighton.

Finally, on September 3, 1965, D-Day arrived at the county board of supervisors where the hearing was conducted under the able leadership of its chairman, Tom Hudson, who, while personally against the project, was fair to all who spoke. After 13 hours of hearing and debates (the hardest fought in the history of the county), the 3–2 decision was finally reached at 3 a.m. to overrule the planning commission and grant the permit for the refinery.

While a broadened tax base and new jobs won out over clean air, the residents of the Montery Peninsula would not give up; they were fighting mad at the supervisors' decision and they immediately circulated a referendum petition to place the questions on the ballot, and within 21 days, 12,572 signatures were gathered. The referendum petition presented to the board of supervisors was rejected by the county counsel stating that the vote was an administrative rather than a legislative act and thus not subject to a referendum. To add a further roadblock, the county clerk would not proceed to verify the signatures on the petitions until instructed to do so by the county counsel. The matter went to court and a judge had to be brought in to hear the case after all Monterey County judges disqualified themselves.

On February 8, 1966, almost one year after Humble had announced its original plans to build the refinery, the court sustained the county counsel's decision. Still undaunted, a new avenue of approach was started to prevent construction of the refinery. The new tack was to obtain proxies and to carry the issue to the stockholders' meeting of Standard Oil of New Jersey, parent company of Humble Oil.

Humble Oil and Standard Oil of New Jersey received numerous letters with credit cards enclosed reminding the oil companies that the card holders did not want to patronize those who would inflict an oil refinery on Monterey Bay.

At last, sensing the severity of purpose, the unity and determination of Monterey County's clean air proponents, Humble began to quietly look elsewhere. On June 11, 1966 it announced receiving a favorable rezoning permit to enable it to locate its refinery near Rodeo on Suisun Bay. On May 17, 1966, Humble Oil finally announced abandonment of its proposed plant at Moss Landing on Elkhorn Slough in favor of a site at Benecia on Suisun Bay near other established Northern California oil refineries. Thus ended the historic battle to save clean air which started on February 15, 1965 and ended on May 17, 1966, and resulted in saving one of the great salt marshes from almost certain death. Humble's clean air problems followed it to Benecia.

The only new industry located on Elkhorn Slough since Humble's departure is a highly successful mariculture plant whose activities are compatible with the preservation of the wetland. Upland development and the possibility of new heavy industries continue to be a threat to Elkhorn Slough; however, Nature Conservancy has acquired some 500 acres within the salt marsh, and Moss Landing ranks among the 10 top priority wetlands for public acquisition in the report entitled, "Acquisition Priorities for the Coastal Wetland of California."[5]

SAN FRANCISCO BAY

The saving of San Francisco Bay, the most important natural harbor on the Pacific Coast, is an outstanding example of effective citizen education and adroit political action which resulted in legislation creating a permanent effective regional agency that preserves, protects, and provides for limited but wise development of the bay in the public interest.

When California was admitted to the Union in 1850, the bay's water surface consisted of 680 square miles. 100 years later, 200 square miles of this water surface was lost by man's activities in diking, filling, reclaiming, and polluting the bay. In addition, 17 square miles of tidal and submerged land had been filled along the waterfronts of bay area cities.

In 1850, 5,000 sea otter pelts were taken in San Francisco Bay. Today, no sea otters are found in the bay. While in 1900, the bay oyster harvest was 10 to 15 million pounds, there is no oyster harvest today. The once prominent San Francisco Bay shrimp industry is practically non-existent and there has been a loss of 1.8 million winter nesting water fowl. The various cities around the bay, by 1950, were slowly but surely looking to the San Francisco Bay as a thing to fill for expanded residential, commercial, and industrial development.

Particularly alarmed about this situation in 1959 was Mrs. Clark Kerr whose husband was then president of the University of California. She was accustomed to meeting at the San Francisco Airport distinguished visitors whom she would drive across the bay to the University of California at Berkeley. Frequently, they commented about the beauty and marvel of the bay, and Mrs. Kerr, while appreciating her visitors' remarks, was also aware not only of the plans of her own city of Berkeley to fill 2,000 acres of the bay, but the plans of other cities to expand into the bay. Mrs. Kerr, disturbed about this damage to a great resource, called a meeting of

[5] Cooperative Report, Bureau of Sport Fisheries and Wildlife—California Department of Fish and Game, April 1974.

university women, a retired Harvard economics professor, and a few conservationists concerned about the future of the bay. This was the start in 1959 of the save the San Francisco Bay effort.

The save-the-bay people's first success was dissuading the Berkeley City Council from filling in its wetlands. They then turned their eyes on the rest of the bay. At Mrs. Kerr's urging, the University of California's Institute of Governmental Affairs studied and published, under the able leadership of Mell Scott, "The Future of the San Francisco Bay,"[6] a comprehensive report showing how the bay's great resources were being destroyed.

How to stop the filling was a difficult regional problem in that the bay's shoreline involved the jurisdiction of nine counties and 32 cities, many having plans to extend their cities beyond their waterfronts. Also included in plans for bay filling were some of the most formidable financial giants of the west. One plan in San Mateo County alone called for an investment of $3 billion, which encompassed bulldozing down of the San Bruno Mountains near the San Francisco Airport to create more flatland for bay development.

There being no existing effective regional body to deal with the problem of bay fill, the save-the-bay group looked to their legislators at the state capitol for aid. Failing to obtain legislative assistance in 1963, they tried again in 1964, this time enlisting the support of Senator Eugene McAteer of San Francisco, a shrewd, tough, and able legislator. McAteer, knowing that he did not yet have sufficient support to control filling of the bay, was nevertheless able to get enacted temporary legislation creating a nine man study commission with a $75,000 appropriation whose purpose was to "define the public interest in the San Francisco Bay—to determine the effects of further filling upon navigation, fish, wildlife, and water pollution," and to report and to recommend legislation in 1965 to protect the public interest in the bay. To the 1965 legislature the study commission recommended that a San Francisco Bay conservation and development commission be established whose duty would be to formulate a comprehensive and enforceable plan to preserve the bay and protect it from piecemeal filling while the plan was being completed.

Coordinated planning for the future preservation, growth, and development of the entire bay area was important in 1965 and there was a need to impose a moratorium on further filling of the bay. Each of these issues would present formidable and perhaps insurmountable political opposition in the legislature. Senator McAteer wisely chose to make the agency's goal single purpose, confined only to the bay itself, and he skirted the question of a moratorium on all filling in the bay by providing power to regulate filling through a permit system. His 1965 legislation was carefully drafted so that it could not be hamstrung by opposing lobbyists.

The save-the-bay group working very hard to muster support in Sacramento was assisted by a popular San Francisco disc jockey who plugged "Save the Bay" daily on his 6 to 9 a.m. show, even calling the governor out of bed to give his comments on the bay! Small sackfuls of sand arrived in legislators' offices with the message, "You'll wonder where the water went if you fill the bay with sediment." Bus loads of people attended all of the committee hearings and, after an extremely hard fought battle, the bill known as the McAteer–Petris Act was passed and became law in June 1965, providing for developing a long range plan for the San Francisco Bay to be prepared by the new bay conservation and development commission. Its members were both elected and appointed, many of them being representatives of governmental agencies—federal, state, county, and city. During the planning stage, anyone wishing to fill or remove materials from the bay was required to obtain a permit from the commission.

In January 1969 the plan, consisting of a set of policies for the future of the bay, was finished and submitted to the legislature. Once again, a major battle ensued, but this time without the leadership of Senator McAteer, who had died. The developers and owners of bay lands regarded the 1969 session of the legislature the last and final chance to forestall regulations that would prevent them from carrying out their development plans for the bay. Likewise, the backers of the bill were most cognizant that its passage would be the final legislative step in providing the guidelines and governmental organization necessary to save the bay. Consequently, both sides worked long and hard in the legislative halls of Sacramento.

After a fierce legislative struggle, followed by a change of leadership in the state senate, people became aroused and a petition three miles long containing over 250,000 signatures was presented to the governor demanding that the bay be saved. Finally, legislation was approved making the commission a permanent body. The law, when signed by Governor Reagan established the San Francisco Bay Conservation and Development Commission (BCDC) giving it regulatory powers over all filling and dredging in the bay, limited jurisdiction over substantial development within a 100-foot strip

[6] Published by University of California Institute of Governmental Studies, October 1963.

inland from the bay, and limited jurisdiction over proposed filling of salt ponds and managed wetlands.

(The Bay Conservation and Development Commission's activities, experience, and personnel laid the foundation for Proposition 20, the Coastal Zone Conservation Act of 1972.)

Of the gallant struggle started by the University woman in Berkeley in 1959, Russell Train, chairman of the Council on Environmental Quality stated:

> Concerned citizens demonstrated a vigor of purpose and a tenacity that outlasted setbacks, and persisted year after year and session after session until the legislature responded. It is as though, having come to the end of a long Westward journey of conquering the land, California contemplated the bay and decided to let it live.[7]

PROPOSITION 20

The November 1972 election in California marked the passage of Proposition 20, California's Coastline Protection Initiative. For more than a century there have been increasing demands and competing pressures for commercial, industrial, residential and recreational uses of the natural resources along California's 1,072-mile shoreline. Committees of the legislature as well as numerous coastal study commissions for 25 years had repeatedly pointed out the inability of local government to respond to the regional and statewide needs to protect California's magnificent and divergent coastal resources.

Conservation groups having been unable in 1970 and 1971 to obtain coastline protection in Sacramento made a herculean effort in 1972 but could not overcome the strength of major lobbying forces in Sacramento. Not to be outdone, California's Coastal Alliance, whose membership induced over 100 civic, conservation, sports, business, and some labor organizations, used California's direct initiative and obtained 500,000 signatures to qualify the Coastal Protection measure for the November ballot. The Alliance under the able leadership of its president, Janet Adams of San Mateo, was able to get the initiative passed by a 55 percent statewide vote. The people of California through Proposition 20 said:

> The permanent protection of the remaining natural and scenic resources of the coastal zone is a paramount concern to present and future residents of the state and nation; and
>
> It is the policy of the state to preserve, protect, and where possible, to restore the resources of the coastal zone for the enjoyment of the current and succeeding generations.[8]

[7] The Saving of the San Francisco Bay, by Rice Odell, published by Conservation Foundation—Foreword by Russell Train, p. VIII.

[8] Section 27001 California Public Resources Code

Proposition 20 did not provide a permanent solution to the coast's problems. What it did do was establish temporary commissions to plan for the future and to temporarily control development by requiring that Coastal Commissions:

1. Prepare a plan for the future of the California coast to be submitted to the legislature before January 1, 1976.
2. Control all development within the state's coastal waters and on land within 1,000 yards of the coast to insure that unwise development does not make the coastal plan useless before it can be completed.

Proposition 20 created one state and six regional commissions which cease to function after December 31, 1976 unless continued by the legislature.

The state commission's able chairman is Melvin B. Lane, who served with distinction as chairman of BCDC. Lane brought with him from BCDC its articulate and experienced executive director, Joseph Bodovitz, who serves as an executive director of the state commission. Also BCDC's former chief planner, Jack Shoup, heads up the planning effort of the state coastal commission.

Public input and citizen participation are most noticeable in both the planning and permit procedures of the coastal commissions.

In developing each of the elements of the preliminary plan extensive public hearings were held by each regional commission as well as by the state commission.

Nine elements of the coastal plan are:

- Marine environment
- Coastal land environment
- Geology of the coastal zone
- Appearance and design
- Recreation
- Energy
- Transportation
- Intensity of Development
- Government organization, powers and funding necessary to carry out the coastal plan.

Of particular interest to protectors of estuaries is that section of the plan dealing with coastal waters, estuaries, and wetlands under the marine element: "All remaining coastal estuaries, wetlands and other buffer areas necessary to protect wetlands and their wildlife and bird habitat values shall be preserved, enhanced, and, when possible, restored."[9]

[9] Preliminary Coastal Plan, p. 39 (Hearing California Coastal Zone Conservation Commissions).

To carry out this objective, the plan proposes that before any alteration of wetlands is permitted an overall plan of the wetland must be prepared and approved by the state commission. New developments in wetlands would be only permitted after there is demonstrated a statewide need and no feasible alternative. The plan also calls for control of development in upland areas adjacent to estuaries so as to prevent adverse impact on estuarine values.

The preliminary coastal plan has been widely distributed throughout the state. In the history of California, no other plan proposed to be submitted to the legislature for consideration and approval has had as much public input and review as the preliminary coastal plan. Public hearings conducted throughout the state encourage citizen participation and input. Many of the meetings have been held at night to enable working people to participate. Individuals and organizations have provided a vast amount of letters, statements, and position papers regarding the plan. As a result of such public input, the preliminary plan will be revised and improved before presentation to the legislature.

Hearings on permit applications for developments have also provided much opportunity for individuals and organizations to participate and present their views to the regional commissions and to the state commission on the appeals, and at each meeting of the state as well as the regional commissions 15 minutes time is set aside to permit any citizen or organization to address the coastal commission on any matter other than specific matters that may be pending before that commission.

The public input at the preliminary coastal plan hearings proved to be enlightening for the individuals and groups who appeared as well as for the commissioners listening to the public comment. Commissioners were berated as being "socialists," "communists," and "dictators", as well as saviors of the coasts, estuaries, plankton, coastal bluffs, and the ocean. The public learned that the coastal plan was a sincere and reasonable effort to save the coast and not, as some critics commented, "a land grab by a starry-eyed group of self-perpetuating bureaucrats." The commissions learned that the plan as presented was perhaps too bulky, was not fully understood by many citizens, and was not likely in its preliminary form to be understood or appreciated by the legislature.

The revised plan was to be presented to the legislature before January 1, 1976. With more than 80 percent of California's population living within a 30-minute drive, the coast needs legal protection. Hopefully, an intelligent support group of informed citizens of California, having lived through and participated fully in the growing pains of the coastal commission will unite to give California the kind of legislation needed. Failure to enact meaningful coastal legislation will result in a return to the wasteful, piecemeal, sprawling development that has overrun many parts of the California coast, congesting coastal streets, walling off coastal vistas, filling bays and estuaries, and denying public access to the coastline.

The decision of the California legislature will be anxiously awaited by users of coastal resources throughout our nation.

WETLANDS AND THE COURTS

The judiciary in California, as elsewhere in the nation, has played a most significant role in interpreting and enforcing environmental legislation. Citizen groups have contributed much in bringing the issues to the attention of the courts and in helping to finance environmental litigation.

The tidelands and wetlands of California have for years been subject to considerable litigation. Title to the tidelands was acquired by the state upon its admission to the Union in 1850. By legislative enactment in 1868 and subsequent amendments the state's tidelands were impressed with a public trust for navigation, commerce, and fisheries. Tidelands embraced in the California statutes have been interpreted by the courts to: "... extend from the Oregon line to Mexico and include the shores of bays and navigable streams as far up as tide water goes and until it meets the lands made swampy by the overflow of freshwater streams."[10]

Among the significant opinions concerning tidelands in which citizen groups played a vital role was the case of Marks v. Whitney[11] decided by the California Supreme Court in 1971. This was an action to quiet title by the plaintiff Marks who owned lands on Tomales Bay, lying between the mean low and mean high tide, a portion of which were in front of defendant Whitney's property facing the bay. Marks sought a declaration from the court that he had a right to fill and develop the tidelands.

The lower court held that defendant Whitney did not have standing to raise the issue that such tidelands were subject to the public trust. The court found that Whitney had an easement to use a wharf across the tidelands property of Marks' subject to Marks' right to fill and develop the tidelands.

Actively participating in the appeal of the trial

[10] People v. California Fish Co. 166 Cal. 576 at p. 591
[11] 6 C3d. 251

court's decision was the Sierra Club on behalf of its 60,000 members, who asked the court to declare the tidelands of Marks' to be subject to the public trust and to find that Whitney had standing to raise the issue. The Sierra Club also asked the court to determine the extent and scope of public easements in navigable waters over tidelands.

The appellate court took judicial notice that Whitney's lands lying between the lines of mean high and low tide were tidelands and were, therefore, impressed with the public trust. This court pointed out that the public trust in tidelands for navigation, commerce and fisheries has been held to include the right to fish, bathe, hunt, swim, and use for boating and general recreational purposes. Of particular interest to protectors of wetland is this language:

> There is a growing public recognition that one of the most important public uses of the tidelands—a use encompassed within the tideland trust—is the preservation of those lands in their natural state, so they may serve as ecological units for scientific study, as open space and as environments which provide food and habitat for birds and marine life, and which favorably affect the scenery and climate of the area.[12]

It also found that Whitney did have standing to sue in that the relief sought by Marks in filling and developing the tidelands would take away Whitney's rights, to which he was entitled as a member of the general public.

A bombshell in environmental law in California is the now famous Friends of Mamouth v. Board of Supervisors[13] involving the construction of a ski lodge in Mono County. The statewide impact of the California Supreme Court's decision is of major concern to wetland protectors as well as to all environmentalists.

Here the developer had obtained a conditional use permit for the construction of two multi-storied condominiums without there having been issued an environmental impact report under California's 1970 Environmental Quality Act (CEQA).[14] The Friends of Mamouth, a citizen action group, contended that CEQA applied to private as well as public projects. The National Environmental Protection Act (NEPA)[15] upon which the California Act was modeled applies to public, not private projects.

The California Supreme Court held that state and local governmental agencies must file an environmental impact report for all projects both public and private which require a governmental permit, lease, or other entitlement for use if such activities may have a significant effect on the environment. Proposed developments in wetlands having a significant effect on the environment are governed by CEQA. Developments on the San Francisco Bay, however, are subject to BCDC (The San Francisco Bay Conservation and Development Commission) and the Coastal Zone Conservation Act[16] governs developments lying within 3,000 feet inland from the mean high tide.

In Lane v. City of Redondo Beach[17] aggrieved citizens established that a court may grant declaratory relief to protect the public's right of access to tidelands and navigable waters.

The city of Redondo Beach had passed an ordinance permitting the closing off of certain city streets. The redevelopment agency under its redevelopment plan had sold off the land on which the streets were located and structures on the land had been completed. The plaintiffs contended that such action denied easy access to the beach for lower income citizens, children, and senior citizens in violation of their right under the California constitution[18] and the government code[19] guaranteeing free and unobstructed access to navigable waters from public streets and highways of a city.

The city countered that it had the right to pass the ordinance closing the streets and unless there was abuse of discretion, fraud, or an ultra vires act the plaintiffs could not attack the city's action. Not so, said the appellate court, adding that a municipality may close off a public street but it does not have the right to close off public access to tidelands or navigable waters.

> The basic purpose of entrusting tidelands to municipalities in trust, is to insure the right of free public access to tidelands or navigable waters. (Calif. Const. Art. XV, Sec. 2 & 3) The object of the trust is destroyed if a municipality . . . can deprive the public of its right of access to tidelands or navigable waters.[20]

Three young men from San Francisco's Lowell High School, disturbed about a development overlooking Lake Merced south of Golden Gate Park, decided to try and stop the project which they felt would cause damage to the lake. Without finances or experience they nevertheless won a $100,000 settlement which was put into a trust fund for coastal environmental protection.

In 1971, for an Eagle Scout project, a 17-year-old boy, Allan Riley, produced a film and report on

[12] Marks v. Whitney, 6 Cal. 3d 251 at p. 259
[13] 8 Cal. 3d 247
[14] Sec. 2100–21165—California Public Resources Code
[15] 42 USC 4321
[16] Sec. 2700–27650—California Public Resources Code
[17] Court of Appeal, Second Appellate District 2nd Civ. No. 45249.
[18] California Constitution, Article XV, Section 2.
[19] California Government Code, Sec. 39933.
[20] Lane v. City of Redondo Beach, ibid.

Lake Merced. He wanted to clean up and preserve the lake and was concerned about a large condominium development under construction on the lake's edge. While Allan was checking various agencies and being brushed off as some kind of "an ecology nut," Proposition 20, California's Coastal Protection Act, became law. He found that the Act provided that if a body of water, not subject to tidal action lies within 3,000 feet inland from the coastline, (i.e., within the coastal zone permit area), the body of water together with a strip 1,000 feet around it shall also be included. He contended that a coastal commission permit was required for such development and one had not been obtained, so he went to court and won a preliminary injunction forcing the developer to seek a permit. For one and a half years Allan carried on the fight alone until he went off to college; then he enlisted two of his former Lowell High School friends, Jonathan Holt and George Duesdieker, to carry on. These young men worked very hard, and for a month never went to bed before 3 a.m. in their diligent efforts to gather all essential facts in preparation for the hearing before the regional coastal commission.

Disappointed that the regional commission granted the permit to the developer, they nevertheless pursued the matter, taking an appeal to the state coastal commission, basing their appeal on inadequate sewage disposal, damage to bird habitat in the lake, traffic density, and earthquake hazard.

The state commission, by a vote of 11–1, denied their appeal in 1973, but the youths would not give up. They interested a San Francisco attorney, Margaret Halloran, in their cause. Struck by their enthusiasm, she represented them in suing both the developer and the coastal commission, challenging the commission's procedures in granting the permit. San Francisco Superior Court Judge Ira Brown issued an injunction stopping the project on October 1, 1973, and then took the matter under submission for 8 months. On June 5, 1974, he informed the parties that he was intending to invalidate the permit and order the case back to the commission. The delay was costing the developers vast sums of money in interest rates alone, so the developer settled in cash for $100,000 with no strings attached. The youths could have kept the money but they preferred to see it go into a trust fund to help environmental causes. Attorney Halloran stated that, without the tremendous research and the fact-gathering by the youths, the case would not have been won. These Lowell High School students proved how effective youth can be in pursuing their legal remedies to a conclusion. They paved the way for others by setting aside their winnings in an environmental trust fund.

LEGAL ASPECTS

LAND USE CONTROLS AND WATER QUALITY IN THE ESTUARINE ZONE

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ABSTRACT

A complex institutional problem has arisen in the management of estuarine resources due to overlapping and contradictory regulatory programs at the federal, state, and local levels. A contributing factor to this problem is the split between regional and community-focused resource management involving state and local land use planning, and specific resource management programs involving federal controls over air and water, and federal review of major construction projects affecting the environment. Noting that state and local government initiatives in control of lands adjacent to estuaries are increasing, and that the federal Coastal Zone Management Act of 1972 was designed to bridge the fields of regional and community-focused management and federal resource management both technically and institutionally, the paper concludes that state-level coastal zone management efforts should be upgraded. Further, coordination requirements included in many federal laws should be given more study and financial support to make them effective.

INTRODUCTION

Most water quality issues have a land use component to them. Site selection for an industrial plant, modification of the land-water interface (the angle and shape of the land being "washed" by the water), and the land use activities affecting water runoff and drainage all affect the quality of the receiving water. The impact of land use on water quality is reviewed by an array of institutions developed in the United States over many years. This paper argues that *our key problem in dealing with estuarine resources is an institutional rather than a technical one.* The technical issues of environmental impact assessment, judicial clarity of private property rights, and others are important, but the primary question is: Who's in charge? This institutional problem arises from numerous conflicting federal and state laws, a federalism system where power is split between states and the federal government, and the current changing role of state and local governments in resource management activities.

For the estuarine zone, the institutional problem arises because of two different factors:

1) Legally apportioned responsibilities among levels of government are based on geographic land-water interactions; and
2) Specific resource management (air and water quality, physical facility development) tends to be considered separately from community-focused resource planning and management.

There are three types of land-water interaction in the estuarine zone, each of which has different sets of institutions for resolving disputes. The first relates to water drainage, water capture, or rights to water use. Private law has developed to accommodate rights of adjoining neighbors in the exercise of these water-related interests. Further, local planning and districting laws frequently aid in accommodating problems between landowners seeking to use the same resource. These water use problems are normally controlled by adjudicating private rights in court, and by actions of local planning and zoning agencies or special districts.

A second area of land-water interaction is called "foreshore," bank, or tidelands where there is a mixture of state and private ownership. Occasionally, rights are totally in one party or another. Sometimes a "public trust" is established and private rights may only be exercised subject to an overriding public interest. Of late, the foreshore area is managed primarily at the state level with federal review where navigable waters are involved.

A third area where land and water interact in the estuarine zone involves waters and waterbottoms in streams, lakes, bays, and other coastal waters where state ownership of waterbottoms and natural resources coexists with the federal navigational servitude. Thus, state law normally controls the resources of the area (fish, minerals, and water consumption) but the federal servitude requires review of most actions to determine impact upon federal navigation and environmental interests.

It is seen that each area of land-water interaction—water use by the landowner, the foreshore, and waterbottoms—has its own primary mixture of institutions regulating and managing the resources. Estuaries, and their associated wetlands and uplands, can, and usually do, involve all three areas thus magnifying the institutional problem.

Critical institutional problems arise because air and water quality issues and physical facility development proposals are managed separately from community-focused resource planning issues. Federal jurisdiction is primarily concerned with the former method of management whereas state and local governments are primarily concerned with the latter.

The term "community-focused resource planning" refers to a number of factors for which it is difficult to find one all-inclusive term. It applies, fundamentally, to human needs in an urban or urban-fringe context, where the needs are reflected in types of land use planning and controls. It refers to procedures to meet housing needs for a diverse population and to meet police, fire, and health standards. It can reflect community attitudes about growth, limits to growth, and quality of construction or aesthetic principles. It can reflect concepts of "key area" or "areas of critical environmental concern." It can consider employment, education, economic and other social needs as a function of land use considerations.

Community-focused resource planning stands apart from specific resource management such as air and water quality controls, water resource development, fish and wildlife impact evaluations, and specific transportation/facility project developments. Specific resource management programs strive for technical precision through alleged objective criteria based on applied research, pilot projects, models, and so forth. They are normally implemented through federal laws and regulations with decisions made by technically trained federal, state, or local officals. On the other hand, community-focused resource planning is controlled almost exclusively by the political process. Implementation of precise technical standards will almost always yield to a hardship case, strong public (or political) sentiments forcing a decision one way or the other, or an emergency situation.

Control of land uses which affect estuarine water quality is caught in a crossfire between the specific resource management functions of federal agencies (EPA—water quality; U.S. Fish and Wildlife Service—fish-habitat improvement; Corps of Engineers—navigation improvement) and community-focused planning considerations such as the need for higher employment, protection of a scenic stream, or housing demands. Local governments responsible for community planning have hundreds of federal regulations and inducement programs to deal with, many of which are competing or contradictory. The difficult struggle in the area of land use controls is to determine when a consideration of community-focused needs should, or could, override specific resource quality standards. Or, to put the case the other way, when should a federal standard, for example, the requirement that structures be elevated above predicted flood stages within a flood plain, control the flexibility of local government to respond to a local community need? The laws, institutions, and administration of specific federal resource management programs and local community-focused resource planning programs reflect this struggle daily.

This paper analyzes this struggle in the context of coastal and estuarine land use problems. For practical and constitutional reasons, a major overhaul of the current system of managing land-water interaction problems is not recommended. However, it is suggested that there are three ways in which the structure can be improved. First, it is recognized that the state level of government could play a stronger role, and perhaps act as a mediator where local community needs and federal resource programs differ. Second, it is recognized that coordination between different agencies having specific management functions needs to be upgraded. Third, there is a need to compile descriptions of experience throughout the world in certain technical matters which can aid in decisionmaking where land-water interaction problems are involved.

To show why these particular institutional problems need attention and to describe ways in which the problems currently arise, four types of management processes used in the estuarine zone are discussed, with emphasis on developments over the last five years. First, the paper discusses federal controls over activities affecting wetlands. Second, major project review at the federal level is discussed. Third, recent developments and initiatives at the local and state level are outlined. Finally, the Coastal Zone Management Act of 1972, potentially an important tool in the future, is discussed. The recommendations stated briefly above are discussed in more detail in the conclusion.

FEDERAL CONTROLS OVER ACTIVITIES AFFECTING WETLANDS

Most marshes and estuarine areas are near or associated with bodies of water that are considered navigable. Tidal waters are considered navigable as are streams capable of conveying any kind of commerce. Where there are navigable waters the United States government has regulatory jurisdiction under the commerce clause of the U.S. Constitution.[1] In recognition of this authority to regulate commerce Congress has granted significant authority to executive agencies to deal with specific resource management activities. For example, the U.S. Army Corps of Engineers regulates activities affecting navigable waters and navigation.[2] The Environmental Protection Agency looks at water quality[3] and air quality,[4] among other things. The U.S. Fish and Wildlife Service and the National Marine Fisheries Service are concerned with fish and wildlife resources[5] of the nation. Each of these agencies, given certain specific authorities and responsibilities by Congress, analyzes the effect proposed activities may have upon these resources by balancing the need for the particular activity with the impact on the resource.

In the last five years Congress, the courts, and administrators have attempted valiantly to upgrade the federal review procedure and make it a workable one. Many of the laws and procedures are still new and many details of this review process have not been fully worked out.

With respect to most activities affecting wetlands primary jurisdiction is in the Army Corps of Engineers under the Rivers and Harbors Act of 1899.[6] When bridges or causeways are involved, the Coast Guard has primary jurisdiction.[7] Any local government or private entity wishing to perform work (water diversions, piers, bulkheads and jetties, drainage, dredging, and others) must apply to the Corps of Engineers for a permit before that work may begin. Originally, the Corps evaluated projects from the standpoint of navigational interests alone. In the last 20 years, however, changes have occurred in this procedure which have substantially expanded it. These will be briefly described.

The Fish and Wildlife Coordination Act[8] was originally passed in 1934 and has been amended numerous times since then. It requires that the director of the United States Fish and Wildlife Service, the National Marine Fisheries Service,[9] and the chief official of the state resource agency concerned with fish and wildlife resources provide comment to the Corps of Engineers on the effect of the proposed project on fish and wildlife resources. These comments are attached to the report of the district engineer and frequently form the basis for denials, compromises, or the imposition of mitigative features as permit conditions and other arrangements between the applicant and the Corps of Engineers. The past decade has seen significant growth in the fish and wildlife review procedure. In August 1974, the U.S. Fish and Wildlife Service published a set of guidelines[10] developed in the past 10 years to assist field personnel review applications for Corps permits.

In recent years other events have occurred requiring that interests beyond navigation be considered by the Corps of Engineers prior to approval of a permit. In 1970, Zabel v. Tabb,[11] decided by the U.S. Fifth Circuit Court of Appeals, held that the Corps of Engineers may deny a permit for activities in navigable waters on ecological grounds alone. It recognized that the Corps must consider the congressional intent in the Fish and Wildlife Coordination Act and the National Environmental Policy Act in its decisionmaking process.

In 1972, three acts were passed, all of which will affect aspects of Corps procedures: the Ocean Dumping Act,[12] the Federal Water Pollution Control Act,[13] and the Coastal Zone Management Act.[14] The Ocean Dumping Act requires the Corps of Engineers to apply Environmental Protection Agency standards and criteria in approving ocean disposal of dredge spoil materials where the transport for dumping passes through U.S. territorial waters.[15] Similarly, under the Federal Water Pollution Control Act of 1972, the Corps must apply EPA criteria in allowing disposal of dredge spoils in navigable waters.[16] Under the Coastal Zone Management Act of 1972, Congress has given states the primary responsibility for determining land and water uses affecting the coastal zone.[17] (The potential effect of this new law is discussed in more detail later.) The precise impact of these three new laws passed in 1972 is still being debated by the Corps of Engineers and other agencies.

In response to these many changes, the Corps of Engineers began modifying its procedures, first, by expanding the definition of the word "navigable waters" to align with the case law developed by U.S. courts in defining the term. By regulation,[18] all waters up to the mean high tide line, including wetlands wholly or partially covered at high tide are included, whether privately or publicly owned. Further, waters which are "navigable-in-fact," and capable of supporting commerce or which in the past, or potentially in the future can become "navigable-in-fact" are included. Most recently the Corps of Engineers issued new guidelines expanding its scope of review over activities affecting navigable waters[19] which provide a higher standard of review when wetlands or marshes are involved.[20]

Currently, wetlands control at the federal level involves the Corps of Engineers (or Coast Guard) as the primary agency with comments, or input coming from many other interests. At the federal level input is received from the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, the Environmental Protection Agency, and, where the nature of the application requires, other agencies of the federal government having an interest. Further, the Corps receives input from state and local agencies having an interest in the project application, the number of agencies varying with the state. Beyond the review exercised by government agencies, the Corps becomes the focal point for pressure from the applicant to have his project approved, and pressure from public interest, environmental, or other groups who oppose the change in the wetlands environment.

If a proposed project is large and potentially damaging to the environment in a "significant" way, or if there is a great deal of public controversy surrounding a proposed project, the Corps may decide that an environmental impact statement must be prepared under the National Environmental Policy Act of 1969.[21] The decision to prepare such a statement is discretionary with the federal agency depending on its interpretation of whether a permit allowing construction is a "major Federal action significantly affecting the quality of the human environment." If an environmental impact statement is prepared the same agencies review the draft statement, or provide input to the Corps as in the case of general permits for activities in navigable waters. The agency and public comments tend to relate to the adequacy of the environmental impact statement as well as the substantive environmental issues. Further, the procedures followed are more specific, resulting, usually, in a more detailed and thorough review. (Review of major public works projects is discussed in the next section.)

Three key matters involving the Corps review process just described will have to be addressed in the coming few years. First, the review process may be too narrow to allow for sound decisions. It is project oriented—the responses relate to a specific action at a particular time. Also, the review is single-resource oriented, i.e., the focus of attention is the single purpose the project is to serve or the effect the project has upon a single resource such as a wildlife habitat affecting one species. Often, impacts on the ecosystem as a whole are not evaluated. Further, the procedure seems deficient in that regional considerations and community-focused resource planning dimensions of review are missing. Receiving input on a specific project proposal from varieties of agencies may not provide the overview necessary for sound management and decisionmaking.

The second matter needing attention in the next few years is the role of the Environmental Protection Agency. In addition to reviewing dredge spoil disposal practices discussed above, EPA reviews all dredging permits to determine impact on water quality.[22] This agency also influences land use decisions greatly through required planning programs.[23] These powers have yet to be implemented for the most part. For example, the New Orleans District of the Corps of Engineers does not get direct input from EPA, but EPA provides information to the Fish and Wildlife Service which combines the information with its review. At the Washington level, there is debate over how extensive EPA and Corps control over dredge spoil disposal should be. Despite these uncertainties, EPA's recent statements regarding protection of the nation's wetlands[24] and land use implications of EPA programs[25] indicate that this agency's review of wetlands decisions will increase in the future.

A third aspect of the federal wetlands control program which may change dramatically in the next few years is the role of state and local governments. Though some states make very specific recommendations to the Corps of Engineers on these matters, other states have not yet developed specific programs. Most states are upgrading current efforts or developing new ones to more effectively manage wetland resources. Some assistance may come as the Coastal Zone Management Act (to be discussed later) is implemented. A key question is whether state authority will increase and replace aspects of federal government review, thus shifting the focus of attention from federal agencies to state agencies. It is possible that states will be given greater consideration and perhaps be the determinative voice in the federal review process. Further, they may be able to better address regional and community-focused considerations.

MAJOR FEDERAL PROJECT REVIEW

Operating parallel to the review of individual permit applications for activities affecting navigable waters is the planning and implementation of major public works projects, normally dealing with utility or transportation development, which affect coastal zone and estuarine resources. Most of these involve significant modification of the land-water interface with resulting changes in water movement and circulation and with notable effects on geology, water chemistry, and biology. Projects in this category include river channel improvement; new roads and highways crossing estuarine areas; large fill projects for airports or port improvements; dams and reservoirs for irrigation and flood protection; major shore protection works to offset erosion, accretion, and sedimentation; stream channelization for drainage; and other kinds of activities.

The Corps of Engineers and other major federal agencies are normally responsible for these kinds of activities. They do not apply for a permit as discussed in the previous section. For the most part Congress determines the rules to be used in deciding when, where, and how a major public works project using federal funds is to be developed. For example, the Department of Transportation administers the Federal-Aid Highway Act[26] which contains numerous requirements for consideration of environmental values in planning and constructing highways. Similarly, the Federal Aviation Administration in airport site selection, the Federal Power Commission in power plant site decisions, and other such agency determinations follow congressional guidelines and procedures. (In the case of the Corps of Engineers, Soil Conservation Service, and others, where Congress has not established specific guidelines in an organic law, the U.S. Water Resources Council has promulgated "Principles and Standards for Planning Water and Related Land Resources"[27] to help establish if a proposed project is in the public interest.) How are federal decisions on major public works projects reviewed for impact on wetlands and estuarine water quality?

The key review of major federal projects is done pursuant to the National Environmental Policy Act (NEPA).[28] Under that act, all federal projects which significantly affect the quality of the human environment must be preceded by an environmental assessment and the preparation of an environmental impact statement. Hundreds of law suits have been filed by environmental protection organizations in recent years using NEPA and the impact statement requirements as their basis.[29] The Council on Environmental Quality which administers the impact statement procedure, has codified much of the case law under this process in their recent guidelines.[30] Further, federal regulations coming from numerous construction agencies over the past year have stressed procedures within that agency for making NEPA reviews.[31]

NEPA review can be criticized from three standpoints. First, the federal agency promoting and developing the project is responsible for preparing the impact statement. They are responsible for conducting an impartial reevaluation of the merits of the project long after the inital decision to proceed with the project has been made. Hence, federal agencies are frequently in the awkward position of trying to respond to the pressures for project review and analysis on environmental grounds and meet requirements under law to proceed with the project.

Second, the procedure of major federal project review is fundamentally a free-for-all. There is no executive guidance to agencies. Major federal agencies which oppose one another on specific projects—e.g., the Corps of Engineers which is sponsoring a major dredging project and the U.S. Fish and Wildlife Service which opposes it—have no arbiter to which to take their claim. The issue frequently becomes political or ends up in litigation. Occasionally through negotiation, interagency agreements on projects are arranged but this is often an exercise in finding a middleground the agencies can live with which may or may not represent the best public interests.

Third, and perhaps the fundamental problem with the procedure for reviewing major federal projects is its "project orientation." The federal agency sponsoring the project must comply with a law designed to promote the project. Congress has passed numerous flood control acts, highway development acts, navigation improvement bills, and many others. The agencies implementing the laws are engineering-oriented agencies with specialized functions. Hence, authority for resource development projects is spread among special-function agencies. This impedes development of a broader approach to determining project need and the consideration of values beyond those immediately associated with the project. What may be missing is a more meaningful role for state and local government in looking at regional considerations and community-focused needs.

LOCAL AND STATE INITIATIVES IN PLANNING AND MANAGEMENT

Theoretically, considerations of community-focused needs and regional concerns are provided by local and state agencies through planning and land use control laws (zoning, subdivision control, eminent domain).[32] Planning and zoning controls arose to serve the need of making land uses in an urban environment compatible. Today, planning and zoning concepts are being applied to new areas of concern arising primarily outside of urban areas.

In the last five years these controls have been significantly expanded to cover coastal zone, wetlands, and estuarine areas. The following are representative examples. Wisconsin passed a Shorelands Zoning Act[34] creating standards for local governmental units to control disturbance of wetlands and shorelines. Delaware recently took action to protect its beach dunes[35] along the Atlantic Ocean. The

State of Washington has passed a Shorelands Management Act[36] which controls all development activities from the line of vegetation to 200 feet inland along the shores of the ocean, bays, and lakes of the state. California has passed recently the California Coastal Zone Conservation Act[37] which, in a zone extending from the 3-mile territorial limit to 1,000 meters inland requires permits for all development activities. The State of Florida passed the Environmental Land and Water Management Act[38] in 1972 which delineates areas of critical state concern and developments of regional impact for application of state and regional policies. Maine has passed a Site Location Law[39] controlling major facility development. Hawaii[40] and Vermont[41] have established commissions which review all major land use activities in these states.

In most of the examples there is a mixture of control activity between state and substate units of government. Traditionally, state law provides general guidance and limits of authority while implementation is at a lower level of government. The courts have upheld these laws as valid exercises of governmental power[42] but occasionally courts restrict the exercise of that power to protect the property rights of the individual affected.[43] Thus, states and local governments are experimenting with new laws and ordinances in controlling key areas and resources normally found outside of the urban environment. This trend will probably continue.

State and local initiatives to plan and manage coastal regions, critical areas, or resources in a key area, must deal with specific resource or project management under federal laws whenever navigable waters or federally assisted programs are involved. For example, in California's coastal area, many activities managed by the California Coastal Zone Conservation Commission are also reviewed by federal agencies having resource or project functions within that region. Potentially, state and local management of regional or community-focused resources can conflict with resource and project management exercised by federal agencies. This has occurred in California where Interior Department's plans for Outer Continental Shelf oil development and California's plans for coastal zone management are bound to conflict.[44] This becomes a struggle between the state's exercise of its police power and the federal government's powers to regulate commerce among the states.

This state-federal struggle gives rise to technical, legal and institutional problems. At the technical level, frequently incompatible results arise from an evaluation of the goals and needs of a particular area (done by the state or local unit) and the analysis of resource or project development under federal standards and criteria. The perspectives of the respective agencies are quite different. From a legal and institutional standpoint, clarification is needed to distinguish between regional or community-focused decisions made at the state and local level and the resource and project management decisions exercised at the federal level. It is uncertain whether the courts must choose between the two or allow the two decision processes to exist side-by-side.[45] Congress may, as a matter of policy, begin to restrict and reduce federal management roles in an effort to upgrade the role of state and local government. With strengthened state and local programs emerging and demanding an effective voice in decisionmaking, a shift in power may evolve over a period of years. This would constitute a reversal of a trend started in the early part of this century whereby Congress used its powers under the interstate commerce clause to exercise many resource management functions at the federal level.

FEDERAL COASTAL ZONE MANAGEMENT ACT

If the state and local initiatives described are to succeed as the mode for regional and community focused management, they must be legally and technically prepared for the job. One law specifically designed to encourage and upgrade state and local initiative in this area is the Coastal Zone Management Act of 1972,[46] a quietly passed, almost unnoticed, bill. The 30 coastal and Great Lakes states (territories and possessions as well) can apply for assistance in the development and implementation of coastal management programs. The key purposes of the law are to balance environmental protection and economic development objectives in the land and water use decisions in the coastal zone, and to upgrade the state's decisionmaking process. States do not have to participate under the Coastal Zone Management Act, but all have.

Initially, states receive planning funds to develop a "coastal management program" which consists of three key elements. The first is to establish the boundaries of the coastal zone. This is a difficult task because the coastal zone is defined as the area in which shoreland uses have a direct and significant impact on coastal waters. Hence, to establish the boundaries of the coastal zone is to establish the uses to be managed. The second element is to develop analytical tools for deciding between alternative uses of land or water in the coastal zone. This consists of developing resource inventories and environmental assessment techniques, identifying areas of particular concern, and determining priority uses for particular areas in the coastal zone. The third, and perhaps the most important element, is to improve the decision-making processes within the states in two ways: raising the level of government at which decisions are made and requiring full cooperation between levels of government; and, outlining the decision-making process between various decisionmakers and determining criteria and standards they are to use.

Once states have developed a coastal management program they apply to have it approved by the administering office (NOAA in the U.S. Department of Commerce). Once approved, the federal consistency provisions of §307 of the Coastal Zone Management Act come into effect. Under these provisions, all federal projects, federal funding, assistance, and permit activities, must be consistent with the state's coastal management program subject to certain qualifications.[47] The §307 federal consistency provisions may ultimately be the handle on which state and local management programs, exercised under the state's police power, can operate at a par with, or perhaps have key influence over, federal resource and project management programs in a particular state's coastal zone.

The coastal management program is very new and many questions remain unanswered. Most states received initial planning grants in June 1974, and the next few years should see considerable planning activity. However, the Act is not adequately funded and even with states upgrading programs rather than starting new ones, progress may come slowly. CZM must gain acceptance within a state as well. Programs in local planning and zoning, fisheries management, mineral production, and water development must be used in the program and coordination between CZM and these traditional resource management programs must be complete.

CONCLUSION

Previous sections of this paper have reviewed four major fields of regulation and control over land uses which affect estuarine water quality: federal controls over activities affecting wetlands and navigable waters, major federal project review, local and state initiatives in planning and management, and the federal Coastal Zone Management Act. As mentioned in the introduction, this paper does not suggest a major overhaul of the system since for constitutional and political reasons this would be nearly impossible. The main problem is an institutional one, and the concern is how to spend funds over the next five or 10 years to meet this institutional problem.

There are three primary ways to upgrade the current system to meet aspects of the institutional problem: greater support for state coastal management efforts; required coordination between federal programs and between federal and state agencies making similar reviews; and further research and information on technical matters relating to land use controls.

State coastal management initiatives should be given greater support as they are potentially the most important component in the review system. It was developed earlier that at the federal level the U.S. Corps of Engineers, with input from numerous other federal agencies, is the key agency deciding uses of wetlands and estuaries, and that under NEPA, federal agencies involved in major projects must prepare environmental impact statements. At the other end of the scale, private interests and local governments either promote and actively seek, or oppose proposed projects and changes in their areas. Hence, much of the dialogue on reconciling resource management and project proposals with community-focused resource needs is between local and federal interests. Missing in this dialogue, and potentially most useful in resolving problems and seeing a broader perspective, is the state level of government.

It has been described how states have begun to take initiatives in the last few years to develop programs where key areas, or regions, are managed at state level or by local governments subject to state standards and review. Since the coastal management program is specifically designed to upgrade the state's role in the management effort, it should be given greater attention. A number of reasons support this view. 1) Most federal officials and resource users feel that land and water use decisions should be made at the lowest level of government possible. They argue that local units tend to be controlled by political interests and thus argue that the state level should be involved as well. Congress specifically expressed this in the Coastal Zone Management Act by asserting that states in cooperation with local governments should be the focal point for coastal management activities. Also, the current trend in federal administrative matters seems to be in the direction of providing more authority and responsibility at the state and local level.

2) Although the land use bill in Congress failed, and many interpret this as an anti-land use control sentiment in Congress, most people believe that the coastal zone is a different, unique, and highly stressed area. Land use controls are normally accepted at the local and municipal level for urban problems. People

seem ready, indeed, to accept land use controls at a higher level of government where urban fringe and non-urban areas are in the coastal and estuarine zone.

3) The Coastal Zone Management Act is conceived and designed to meet the key coastal and estuarine problems. It combines technical and institutional upgrading as its primary goal, requiring states to address both the question of the manager and the criteria the manager uses for making decisions. The coastal management program is not conceived in isolation from ongoing programs but specifically requires coordination and resolution of differences between state, local, regional, and federal agencies. Further, the policies of the Coastal Management Act seem most suited to resolving tough coastal zone controversies. It is not a mission oriented program but is specifically designed to balance environmental and economic development objectives through analytical techniques and procedures. Finally, it has no vested interest to assert although some have accused it of being a special interest program in its assertion of the importance of the coastal zones over noncoastal areas.

4) Finally, the coastal management program is designed to look at both land and water uses and the interaction between the land and water. It is not limited from a geographical standpoint as is the Environmental Protection Agency ("waters of the United States"), the Corps of Engineers ("navigable waters") or the U.S. Fish and Wildlife Service ("navigable waters"). It can include adjacent uplands as well as water bodies in the definition of the coastal zone. This may facilitate providing a nexus between the community-focused resource planning typical of the local government unit, and the specific resource or project management functions of federal agencies. It also affords an opportunity to consider regional problems from both the community need perspective and the resource/project perspective.

In a recent publication a suggestion was put forward that a program of wetlands control is needed similar to the Federal Water Pollution Control Act of 1972 wherein federal authority would be paramount and specific standards would be promulgated for implementation at the state and local level.[49] This would be an unwise approach. First, it would separate wetlands from associated upland areas thus inhibiting the ability to control the major source of the impacts on wetlands and estuaries. Second, such a wetlands control program would be aimed at enhancement of fish and wildlife resources dependent upon the wetlands resource which, as mentioned before, may not give sufficient consideration to community-focused needs and regional concerns.

There is a difference in philosophy in the approach of the Coastal Zone Management Act and the Federal Water Pollution Control Act. The Coastal Zone Management Act stresses that states should be given maximum flexibility under very general guidelines issued at the federal level; these guidelines relate to the process, not the substance of decisionmaking. The Federal Water Pollution Control Act mandates that federal standards be developed for all emissions and effluents and that states implement these standards. The coastal management approach seems sound in the long run. Where guidelines provide for flexibility and innovation at the state and local level, commitment to the program by state and local officials becomes greater. They are more likely to support its implementation after participating in the formulation of the program.

Further, states differ geographically, socially, and politically. If programs are developed which recognize differences and peculiarities of a state or local area, officials may be more motivated to influence their own people to accept the program than they would be if the program were designed at the federal level. Two states come to mind as examples of these points. California is a leader in the nation in the development of controls over coastal development, perhaps because they have the greatest problems to solve and a highly educated and active citizenry. They will probably progress at a greater speed implementing their own program than would a federal agency implementing a national coastal program in California. On the other hand, Louisiana is a conservative southern state, predominantly rural (with the exception of New Orleans) and with problems of educational, economic, and cultural lag. A great deal of pushing at the federal level will not make a significant difference in Louisiana. Yet, when a local project or program is conceived and executed within the state, the local politicians put a great deal of weight behind it and see that it is developed.

The second major area where the current system of land use controls affecting estuarine water quality can be upgraded is in the *required coordination between certain federal programs and related federal and state agencies granting permits and licenses.* This coordination needs more structuring and funds should be provided for the coordination function. A few examples will illustrate the need and perhaps suggest some remedies. Under the National Pollutant Discharge Elimination System administered by EPA,[50] a certification must be made to the Corps of Engineers that a proposed activity in navigable waters will not adversely affect water quality. Since EPA's primary responsibility is to issue permits to numerous point source emitters, this coordinating mechanism on Corps wetlands permits has been put at the bottom of the list of priorities; yet, this might be one of the most significant inputs to the Corps of Engineers on wetlands permits. Specific funds should be established to facilitate this review, and the factors to be analyzed should be articulated and described in a manual or workbook.

Another area where better coordination is needed is between state and local wetlands review programs and the Corps of Engineers' permit program. Most states are not equipped or staffed to make adequate input to the Corps on these activities. Federal personnel could be detailed to state offices to assist in providing this input where the primary permit activity is a federal one. Training programs involving state and federal officials are needed to sensitize officials to attitudes and perceptions at the other level of government.

A third area where coordination is badly needed is between state and local efforts at managing coastal resources and other U.S. proprietary functions, especially those associated with offshore oil and gas leasing, coast guard and military bases, and other federal land management functions. There have been frequent instances of differences of management philosophies and management techniques between adjacent federal and state lands in the coastal zone.

Lastly, certain *technical matters* need greater attention if the proper procedures and tools for determining land use and water quality interaction are to be developed. First, the concept of an impact beyond local significance needs to be made operational so it can be used in decisionmaking with some degree of consistency. In the areas of ecology, economics, transportation, and others, tools and techniques are needed for measuring or assessing the extent of impact or significance of a local decision. Second, the cumulative effect of many small, individual decisions affecting coastal land and water use must be determined. Techniques and tools are needed to measure cumulative effects. Third, land use controls have traditionally included government restrictions imposed on private land use in specific districts. Recently, ideas have been discussed called "positive land use controls" involving tax incentives, land trades, transfer of development rights, and so forth.[51] These are designed to offset the inequities resulting from imposition of certain land use controls. Also, they provide greater flexibility in forging new land use control strategies. These three technical matters are not readily "solved," nor are there easy "answers." A better approach in providing assistance to agencies dealing with these matters is to compile and describe experience in this country and abroad, and present that experience in compilations in which the materials are well indexed and abstracted.

FOOTNOTES

[1] U.S. Constitution, Art. I, Sec. 8.

[2] 33 U.S.C. §403

[3] 33 U.S.C. §1251 et. seq.

[4] 42 U.S.C. §1857 et. seq.

[5] 16 U.S.C. §661 et. seq.

[6] 33 U.S.C. §403

[7] 49 U.S.C. §1165g(6)(A). When "Corps" is referred to throughout this paper, "Coast Guard" could be inserted if the project proposed is a bridge or causeway.

[8] 16 U.S.C. §661 et. seq.

[9] The NMFS was originally part of the U.S. Fish and Wildlife Service at the time the Fish and Wildlife Coordination Act was enacted.

[10] "Guidelines for Review of Fish and Wildlife Aspects of Proposals in or Affecting Navigable Waters," 39 Fed. Reg. 29552 (1974).

[11] 430 F. 2d 199 (1970)

[12] Marine Protection, Research and Sanctuaries Act, 33 U.S.C. §1401 et. seq.

[13] 33 U.S.C. §1251 et. seq.

[14] 16 U.S.C. §1451 et. seq.

[15] 33 U.S.C. §1413

[16] 33 U.S.C. §1344

[17] 16 U.S.C. §1452

[18] 33 C.F.R. §209.260

[19] 33 C.F.R. §209.120

[20] 33 C.F.R. §209.120 (g)(3)

[21] 42 U.S.C. §4321 et. seq.

[22] 33 U.S.C. §1341

[23] 33 U.S.C. §1288 and §1313

[24] 38 Fed. Reg. 10834, March 20, 1973

[25] Environmental Protection Agency, "Land Use Implications and Requirements of EPA Programs" (undated draft), 13 p. See also F. Bosselman, D. Fuerer and D. Callies, EPA Authority Affecting Land Use (undated manuscript prepared for Environmental Protection Agency).

[26] 23 U.S.C. §101, et. seq.

[27] 38 Fed. Reg. 24778, Sept. 10, 1973.

[28] 42 U.S.C. 4321, et. seq.

[29] F. Anderson, NEPA in the Courts, Resources for the Future (Baltimore: 1973). Legal and non-legal literature has dealt with NEPA at length in recent years.

[30] 40 C.F.R. §1500

[31] See, e.g., "Housing and Urban Development, Environmental Review Procedures" 24 C.F.R. §58 (39 Fed. Reg. 36554, Oct. 10, 1974); "Department of Transportation Procedures for Considering Environmental Impacts" 39 Fed. Reg. 35234 (Sept. 30, 1974); "USDA Forest Service, Environmental Statement-Guidelines for Preparation" 39 Fed. Reg. 38244 (Oct. 30, 1974).

[32] The authority for these controls arises out of the state's police powers. In most cases, state legislatures have delegated the exercise of the power to local units of government. Courts have been the prime agency determining whether controls exceed constitutional limits by denying the land owner the due process requirement that just compensation be paid for a "taking" of land. See F. Bosselman, D. Callies and J. Banta, The Taking Issue, Council on Environmental Quality (1973).

[33] See, generally, F. Bosselman and D. Callies, The Quiet Revolution in Land Use Control, Council on Environmental Quality (1971).

[34] Wis. Stat. Ann. §59.971 (Supp. 1973).

[35] 7 Del. C. §6801 et. seq.

[36] Wash. Rev. Code Ann. §90.58.010

[37] 3 Pub. Res. Code 27000 et. seq. (Dec. 1973).

[38] 26 Fla. Stat. Ann. §§380.012–380.10

[39] 38 M.R.S.A. §481–488.

[40] Land Use Law, Haw. Rev. Stat. Ch. 205.

[41] Environmental Control Law, 10 Vt. S.A. §§6001–6091 (Supp. 1970).

[42] See Just v. Marinette County, 56 Wis. 2d 7 (1972) upholding the Wisconsin Shorelands Management Act; and, In the Matter of Spring Valley Development by Lakesites, Inc., 300 A 2d 736 (Me. 1973) upholding the Maine Site Location Law, 38 M.R.S.A. §481 et. seq.

[43] See State v. Johnson, 265 A 2d 711 (Me. 1970) construing the Maine Wetlands Act, Me. Rev. Stat. Ann. 12, §4701 et. seq., and San Diego Coast Regional Commission v. See the Sea, Ltd., 109 Cal. Rptr. 377 (1973), limiting the application of the California Coastal Zone Conservation Act, Pub. Resources Code, §27000 et. seq.

[44] Hearings before National Ocean Policy Study, U.S. Senate Committee on Commerce, Santa Monica, Calif., Sept. 27, 28, 1974.

[45] See, Askew v. American Waterway Operators, Inc. 93 S. Ct. 1590 (1973); Hershman and Folkenroth, "Coastal Zone Management and Intergovernmental Coordination," 54 Ore. L. Rev. 13-33 (1975).

[46] 16 U.S.C. §1451. Federal assistance in land use planning activities in the past has been limited primarily to comprehensive planning under the HUD 701 program. An attempt to pass a land use planning bill (H.R. 10294) was recently defeated by the U.S. House of Representatives on June 11, 1974. It may be considerable time before it is again addressed by Congress. This leaves the Coastal Zone Management Act as the only federally approved land use program at this time. Land uses under the law are limited, however, to those having a direct and significant impact on coastal waters.

[47] They are to be consistent "to the maximum extent practicable" in some cases, in other cases certifications of consistency must be filed, and in some cases disputed matters are to be resolved by the Secretary of Commerce in consultation with the Executive Office of the President. The reader is referred to the text of §307.

[48] "The Wetlands: How Well Are They Protected?" Conservation Foundation Letter, Sept. 1974.

[49] Id., at p. 8. The idea is attributed to "some environmentalists" by the publication's editor.

[50] 33 U.S.C. §1251 et. seq.

[51] See, e.g., "Inroads Toward Positive Land Use Management," State of Oregon (Executive Department) 1974; I. Heyman, "Innovative Land Regulation and Comprehensive Planning," Santa Clara Law., 13:185–235, (Winter 1972); D. Listokin, ed., Land Use Controls: Present Problems and Future Reform, Center for Urban Policy Research (Rutgers Univ. 1974).

STRUCTURING THE LEGAL REGULATION OF ESTUARIES

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ABSTRACT

Estuaries are large scale, highly productive physical systems. Regulation and management of estuarine resources is divided among a multitude of agencies at all levels of government. Federal regulation has operated through expanding the mandate of federal agencies to include review of most estuarine resources and consultation with agencies responsible for them. The weakness of this system lies in (1) the unwillingness of the agencies to accept the expanded mandate; (2) the lack of agency expertise to comply with the expanded mandate; (3) the failure to fully staff and fund the consultation mechanism; (4) unequal distribution of resources between the public, private, and governmental bodies. This can be remedied by (a) funding public groups which contribute to agency proceedings; (b) establishing national estuarine laboratories with mixed research and regulatory responsibilities; (c) full funding and staffing of the consultation mechanism.

INTRODUCTION

Estuaries are large scale physical systems of high biological productivity and great complexity dependent on land, freshwater and saltwater components for their natural operation. The estuarine environments support both resident and highly migratory biota, both fish and fowl. The protection of the biota is now a national goal under the Federal Water Pollution Control Act Amendments of 1972.[1] The physical position of estuaries at the confluence of rivers with the ocean has also made them natural foci for the development of commerce and the industrial and urban centers which feed commerce.

The legal mechanisms which control the development and use of the estuarine zones are enormously varied and serve a wide variety of policies: the land use regulations governing shorelands and wetlands which traditionally have been developed and enforced by local government; the technological water pollution control programs affecting particular discharges to the waters; water quality standards governing the water itself; structural schemes of water diversion or of damming, in all of which there is typically a shared federal and state responsibility; and the direct regulation of biota exploitation through fishing and hunting laws developed by the state. Typically, these authorities are divided between different levels of government—federal, state and local—with a number of agencies within each affecting the various elements of the estuarine system.

This paper will focus on the biological production of an estuarine system in order to analyze a typical interaction of legal authorities affecting the estuary's ability to meet its potential for biological production. The emphasis will be on the Hudson estuary and its fishery since legal controversy there has helped to illuminate the practical operation of regulatory authority; the aim is not to deal directly with environmental problems on the Hudson but to put the operation of legal institutions into a concrete context. The paper focuses on the distance between the role theoretically and actually performed by the regulatory agencies and the clash of interests which influences their operation. It suggests methods of structuring the agency–private interest relationship to assure more effective resolution of competing demands on estuarine resources.

SCHEMES OF LEGAL REGULATION

There are at least four models for establishing legal safeguards for the productive capacity of an estuary. First, would be a single agency with regulatory authority to license and control the entire array of human activity affecting the life support system and capacity of the estuary. Logically, the agency would have to have regulatory authority over most use and development of the estuary, its adjacent shoreline, its upstream freshwater sources and the exploitation of its biota both inside and outside the estuarine zone. Second, there is the model of an advisory commission establishing a general plan for protecting the biota. This plan would be considered by each regulatory agency deciding land or water uses, but which would not itself have direct jurisdiction over the estuarine zone. Third, a requirement could be made of each agency that it must consider and assess the impact of any proposed action on the productive capacity of the estuary and take necessary steps to protect or minimize the damage to the resources. Fourth, a single agency could be responsible for protecting the productive capacity of the estuary. The authority of such an agency could be either advisory or include the power to reject the proposals of other agencies. Under each model, of course, the objective can be altered to assure the biological productivity of the estuary either greater or less weight in the decisionmaking process.

Examples of the first two models can be found in the Delaware River Basin Commission[2] and the New England River Basin Commission,[3] but they have not been the primary force in recent years affecting the regulation of the estuaries. For instance, the proposal for a Chesapeake Bay Commission in Maryland to control the use and development of Maryland's side of the bay failed of enactment.[4]

In recent years, legislation has moved in two distinctive directions. First, the mandates of federal and, in some cases, state agencies have been widened beyond their primary missions by requirements to consider and weigh the environmental impacts of the agency's activities. The National Environmental Policy Act (NEPA) is the most obvious example of such a mandate-widening statute which requires a fresh look and a new balance from agencies with traditionally narrow mandates.[5] Other examples may be readily found. The courts have reasserted the broad mandate of the Federal Power Commission, so that that agency must look at a broad spectrum of concerns in licensing hydroelectric projects.[6] The land use planning sections of the 1974 Housing and Community Development Act have been expanded to require recipients of planning grants from the Department of Housing and Urban Development to consider environmental issues.[7]

Second, a number of statutes have been enacted which look at particular environmental media or physical areas and require a new, environmentally-protective analysis in the decision process which governs their use and development. The Federal Water Pollution Control Act Amendments of 1972,[8] state wetland protective statutes,[9] and the Coastal Zone Management Act[10] are examples of this approach. These legal structures do not directly focus on the estuarine zone, but they operate within it to produce an overlay of review and analysis which takes into account, to at least some extent, the productivity of estuaries. Most of these statutes as well as others already on the books require resource planning or protection which, if followed through in action, will have long-term impacts on the estuarine productivity.

These new statutory initiatives take their place in a context where some agencies with focused resource responsibilities are also required to consult with state or federal agencies which directly engage in, or license private parties to engage in, the alteration of environmental conditions. These referral and consultation requirements are established to protect the resource. In the context of protecting estuarine biota, the most important of these statutes is the Fish and Wildlife Coordination Act[11] which requires consultation on wildlife preservation with the Fish and Wildlife Service of the Department of the Interior and National Oceanic and Atmospheric Administration of the Department of Commerce. Obviously, NEPA has the same type of consultation requirement.

These legal regulations work as a composite of the third and fourth models set out above. Many state and federal agencies have been given expanded mandates both in land and water resource planning, and in controlling sources of pollution or other factors affecting estuarine productivity. These agencies are required to consult particular agencies assigned to protect certain values in estuarine development.

This legal structure and management model are likely to be the basic pattern for some time to come. It is therefore worthwhile to identify the salient aspects of the model which are essential for its proper operation and analyze whether thay have operated effectively and, if not, suggest how they can be improved. This is done in the context of the Hudson and its fishery in order to give the general point concrete focus. The operating records of the Federal Water Pollution Control Act Amendments of 1972 and the Coastal Zone Management Act are too brief to allow review of their effectiveness in addressing the issue in this context. NEPA and the state wetlands statutes now have longer histories which make them useful for analysis. The emphasis here will be largely on NEPA for a number of resons: it is a federal statute and thus more relevant to Congress's concerns; it is central to an analysis of both the expanded mandate and referral and consultation mechanisms; the principal restraints on state wetland legislation stem from the constitutional requirements of the Fifth Amendment that private property not be taken for public use without just compensation—thus these restraints cannot be directly remedied by legislation.

THE CYCLE OF THE HUDSON FISHERY

The Hudson is a tidal estuary from New York City to Troy, north of Albany. The line of the salt front varies with the freshwater discharge but is generally 40–65 miles upstream from the Battery. Gross pollution problems have been concentrated at New York City and Albany and the central reach of the estuary has historically supported a highly productive fishery.

Henry Hudson reported the river teeming with "the finest fish among which was the shad and many kinds scarcely less delicious . . . there were plenty of sturgeon which the Christians do not make use of, but the Indians eat them greedily . . . herring were in myriads."[12] In the early 19th century, the sturgeon were so abundant that they were known as "Albany beef" and there was a flourishing caviar industry.[13] Today, the striped bass and the shad are the most important sport and commercial fish. There is a wide diversity in the array of migratory and resident fishes in the river, alewife, blueback herring, white perch, bay anchovy, and tomcod, among others.[14]

The life cycle of the anadromous, estuarine-dependent fish is significant to understanding the variety of places at which uses and development can affect the capacity of the river's productive resources. The striped bass may be taken as an example of the life cycle of the anadromous fish for these purposes. In the spring, the adult stripers come upstream from the sea and the over-wintering areas in the Hudson Estuary into the estuary's freshwater section. The extent of the upstream migration depends on the water temperature and on the location of the salt front. In most years, the bulk of the eggs are spawned between 50 and 100 miles upstream from the Battery during May and early June.

The striped bass eggs are released free into the water and drift with the flow of the currents. During the first six to eight weeks of life, the striped bass pass through egg, yolk-sac larval, and larval stages and enter the early juvenile stage. During this period, the organisms gain mobility but their gross movements are determined by the hydrology of the tides, currents, and saltwedge. At the end of the planktonic stage, the young bass begin to move into shallow water, either along the shore or on shoals. These shallow areas are the nursery habitat of the fish during the first year of life.[15]

The young striped bass spend their first winter in the Hudson and then start to move into the sheltered coastal waters. With increasing age, the fish make longer migrations into more open waters. There is no question that the Hudson makes a major contribution to the coastal stock of striped bass in the waters of the New York Bight and Long Island Sound and perhaps is a major source for the fish along the entire south shore of Long Island and in New England waters.[16]

It is obviously possible to affect the estuary's production of striped bass or other biota, both in the short and the long run, by altering the conditions which foster continuing high production and control survival during each phase of the fish's life cycle. In the Hudson many such intrusions have taken place. Historically, there has been intrusion on the adult population through the fishery catch, so that by the mid-1930's, when a 16-inch size limit was imposed, the stock was at much lower levels than it is presently.[17] There has been intrusion on the migratory, returning spawners through catching in nets set in the Hudson for the taking of shad, which also take striped bass.[18] Recently, there has been intrusion on the early life stages of eggs and larvae by entrainment of the fish through the cooling systems of power plants on the Hudson, and there has been intrusion on the juvenile stage through impingement of those fish on the screens of power plant intakes on the river.[19]

Obviously, other equally serious intrusions are possible. For instance, the striped bass population of the Delaware River has been virtually decimated due to gross pollution, mainly oxygen reduction, in the crucial reach around Philadelphia.[20] The central Hudson from the Tappan Zee to Coxsackie is the crucial area for the spawning and nursery habitat and has been relatively clean, but if industrial and municipal pollution on the scale present at New York City or in the Albany pool were to occur here, the Hudson-supported striped bass population could be severely reduced. On the Sacramento-San Joaquin system, the population of striped bass has been halved, apparently by the effect of water withdrawal for irrigation purposes which also withdraws the eggs and larvae from the river.[21] Were the proposal to withdraw freshwater for municipal use from the Hudson at Hyde Park to come to fruition, a similar effect would become a real possibility on the Hudson.[22] If dams were to be constructed on the river, as has happened on the Susquehanna, there would be a major disruption of the spawning run and a consequent effect on the juvenile and adult fish population. Extensive filling of the remaining shallow areas of the Hudson, particularly in the Tappan Zee and Haverstraw Bay, would deprive the fish of its juvenile habitat.

This catalogue indicates the broad range of activities that have to come within legal control if the basic productivity of an estuary is to be protected and preserved and even if development and exploitation of the resource are to be properly analyzed and managed.

THE EXPANDED MANDATE SCHEME AND THE HUDSON EXPERIENCE

Over the last 10 years, there has been continuing controversy in the Hudson estuary over the effects of proposed developments, particularly power plants, on the fishery of the river. This controversy illuminates development under statutes providing for the weighing of competing interests by administrative agencies under expanded mandates which include consideration of estuarine productivity. It also allows analysis of the operation of the referral and consultation mechanisms.

The fishery issue was first raised on the Hudson in the early 1960's in connection with Consolidated Edison Company's application to the Federal Power Commission (FPC) for a license to build and operate the Storm King pumped storage project at Cornwall about 56 miles upstream from the Battery. Storm King would pump water from the Hudson to a reservoir from which it would be released to produce hydroelectric power.[23] The water withdrawals required to run the plant would be of great magnitude—averaging 15–18,000 cubic ft/sec over an 8-hour pumping period each day.[24] After a cursory review, the FPC granted Con Edison the license.

The license was challenged by a citizens' group and in Scenic Hudson Preservation Conference v. FPC,[25] the Second Circuit Court of Appeals ordered the FPC to reconsider the issuance of the license. The court decision required the FPC to allow citizens' groups to present their evidence and arguments to the Commission and laid on the Commission the affirmative duty of building a full factual record on which to base a reasoned decision. The extent of the record was determined by the broad mandate of the Federal Power Act, which required the FPC to determine that the project "will be best adapted to a comprehensive plan for improving a waterway . . . for the use or benefit of interstate or foreign commerce, for the improvement and utilization of waterpower development, and for other beneficial public uses, including recreational purposes."[26]

The court's interpretation of the statute made it the functional equivalent of NEPA's expanded mandate requiring that the analysis by the FPC look at the broad range of public interests affected by the project and also consider possible alternatives. One of the issues singled out for consideration by the FPC on remand was the entire fishery issue, particularly the effect of Storm King's operation on the striped bass and the shad. Thus, because of the 1965 decision in Scenic Hudson, there began to function in the Hudson estuary a NEPA type of expanded review, five years before that statute was passed.

The FPC delegated the fishery investigation responsibility to the Hudson River Policy Committee, a group formed for the purpose and made up of representatives of the U.S. Bureau of Sports Fisheries and Wildlife, the old Bureau of Commercial Fisheries (now the National Marine Fisheries Service), and the Fish and Game Departments of New York and New Jersey, with an observer from Connecticut.[27] Most members of the policy committee were not professional experts on the Hudson fishery and so they in turn oversaw the work of hired consultants.[28] The results of a 3-year research program were published as the Hudson River Fisheries Investigation 1965–1968 (HRFI).

The analysis undertaken in HRFI focused primarily on the striped bass population of the Hudson. The final report concluded that the project would not have a significant effect on the striped bass fishery, since it would take at most 4 percent of the striped bass eggs and larvae from the river.[29] The investigation was completed and the report published after the remanded hearings before the FPC were concluded, so that the Power Commission took official notice of and relied upon the HRFI conclusions but never exposed them to critical examination in a hearing. The necessity of looking at the Storm King withdrawals in the context of withdrawals by other plants on the Hudson is mentioned in the HRFI conclusions, but no analysis of total withdrawals on the river was undertaken. This would, of course, appropriately come within the ambit of the FPC's responsibility to see that the project was in keeping with a comprehensive plan for development of the waterway.

The HRFI report provided an essential data base on the Hudson fishery, particularly the striped bass. But it was not an exhaustive review of the entire life cycle of the fish. HRFI provides a thorough examination of the distribution and abundance of the eggs, larvae, and juvenile stripers in 1966 and 1967 throughout the Hudson with a more detailed study around the plant site in 1968. There is no discussion or analysis of the relation of the Hudson-spawned fish to the coastal stock, nor is there any attempt to judge the productive capacity of the estuary against its actual production. In other words, it does not address the general management of the fishery. Most importantly, while the collection and presentation of data in the report was generally considered to be of high quality, later analyses showed that the calculations which related the plant's operation to the withdrawal of organisms from the river were seriously flawed. The analysis underlying these calculations was not consistent; a dynamic analysis relating the rate of withdrawal to the river flow past the plant compared the plant's withdrawal rate to the tidal flow and not to the net downstream flow; in the static analysis a daily withdrawal rate of absolute numbers of organisms was presented but the withdrawals were not cumulated over the season.

It was some years before these facts became clearly known to the interested public. They were not apparent at the time when the court of appeals reviewed the construction and operating license which the FPC issued to the company in 1970. That license was approved in the second Scenic Hudson case.[30] The analysis of the failings of the HRFI report did not come in an FPC proceeding but rather in a NEPA proceeding before the Atomic Energy Commission (AEC).

When NEPA became law in 1970, serious plans or construction were going forward at four power plants in the central reach of the Hudson which would affect the estuary's fishery—the Indian Point 2 and 3 nuclear units were in construction, and the Bowline and Roseton fossil fuel units were about to begin construction. Starting in 1972, hearings were held under the NEPA mandate before an Atomic Energy Commission licensing board on the Indian Point 2 plant, which is 13 miles downstream from Storm King and designed to withdraw less water from the estuary—800,000 gallons per minute. Here, from the beginning, the major environmental issue was the effect of plant operation on the biota and the biological productivity of the estuary, particularly through the entrainment of eggs and larvae through the plant.

The analysis of the Indian Point plant, conducted by AEC experts from the Oak Ridge National Laboratory, built on the foundations of the HRFI report, and thus essentially limited its analysis to the striped bass. It included a hydrological computer model to power the organisms through the estuary under various freshwater flows and added an analysis of the relation of the Hudson spawning grounds to the coastal stock of striped bass and at least a basic analysis relating the Hudson's productive capacity to its actual production. On this basis, the Oak Ridge staff concluded that the Indian Point 1 and 2 plants would take between 30 and 50 percent of the annual production of striped bass in the Hudson which would be reflected in a similar decline in the size of that year class when they became adults.[31] The Hudson River Fishermen's Association (HRFA), a group of sport and commercial fishermen and conservationists, participated in the hearing as intervenors, providing a non-computer model analysis which reached essentially the same conclusions as the Oak Ridge staff.

Con Edison opposed this interpretation of the data, putting forward its own analysis of the HRFI material in a different analytical model. The predicted effect on the Hudson striped bass production was small, in the 2–6 percent range. A sensitivity analysis of the model's operation showed that the major factor in the differing results was the inclusion by Con Edison's experts of a compensating mechanism in the model which was density dependent and thus increased the survival of the remaining population as the plants reduced the population. The company further denied the major contribution to the coastal stock of New York and New England which was put forward by the Oak Ridge staff. More importantly, on the grounds that there was not enough data to analyze the impact of the plant, the company launched a major research program to determine, by a study to be conducted before and after operation began, what the effect of the plant's operation on the fishery would be.

At the close of the proceeding in 1974, the AEC, while not accepting all the analysis of the Oak Ridge staff and HRFA, agreed with their ultimate conclusion and required Con Edison to install a closed-cycle cooling system at the Indian Point plant but also gave the company a chance to ask for an amendment of the license terms if the research program led it to believe that such a change was justified.[32]

During the same period, the Army Corps of Engineers approved construction permits for the two fossil fuel plants on the Hudson. In March 1970, the Corps approved the construction permit for the 1200 megawatt Roseton plant owned jointly by Central Hudson Gas and Electric, Con Edison, and Niagara Mohawk. The plant would withdraw 650,000 gals/min from the river at approximately river mile 65. The Corps did not undertake any NEPA impact study on the plant. In 1971, the Corps allowed work to go forward on the construction of the Bowline plant, another 1200 megawatt plant withdrawing 750,000 gals/min from the Hudson and set back from the river on Bowline Pond at approximately river mile 37, without the completion of a NEPA impact statement. That plant is owned jointly by Orange and Rockland Utilities and Con Edison. Both plants are within the central reach of the Hudson, and it is self-evident that they present the same fishery issues as does Storm King or Indian Point. The Corps circulated a draft impact statement on Bowline in 1971, but its analysis of the impact on the fishery was so limited and cursory that one was hard put to realize that the plant was to operate on the same river with Indian Point and Storm King. In December 1972, two suits were filed against the Corps of Engineers by HRFA over the Corps' failure to carry out a NEPA analysis on either of these plants before construction began.[33] Settlement agreements have been reached in both cases; the Corps has agreed to undertake a NEPA impact study at Bowline and to analyze the Roseton plant in conjunction with the Bowline statement.[34] At the same time, the Corps has stated in the consent decree that it does not have the manpower and expertise to analyze the fishery issues at stake and therefore the utilities, as part of the settlement, have provided the Corps with $75,000 to hire an outside consultant.[35]

Just as the analysis conducted for Storm King laid the foundation for the expanded analysis at Indian Point, so the work done at Indian Point indicated the flaws of the Storm King analysis and led to a request for further consideration of the fishery issue in relation to Storm King. On the basis of both direct analysis of the HRFI calculations and an estimate of the withdrawal of striped bass eggs and larvae by Storm King made with the model developed to analyze Indian Point, estimates were made by Oak Ridge and Brookhaven National Laboratory personnel and HRFA's expert that 30–40 percent of the eggs and larvae in the river would be withdrawn annually by the Storm King plant. These analyses were presented to the FPC in early 1973 with a petition for further hearings on the impact of the plant on the fishery. The FPC refused to hold hearings on the data and analysis, and an appeal was taken to the Second Circuit Court of Appeals which in May 1974 remanded the fishery issue back to the power commission for immediate hearings.[36]

The remanded hearings are now underway, but have quickly passed beyond the analytical failings of the HRFI report. The new research effort that Con Edison launched in response to the Indian Point proceedings in 1972, and as a further preoperation study of Storm King, is now producing data, and this material is now being reviewed before the FPC in the Storm King proceeding. Thus, the major issues addressed at Indian Point are being worked over again, but with a major added round of factual data as well as further refinements of the computer models.

Further data collection is underway from the utilities and further agency review of the material is to be expected. It is likely that EPA will have to work through the data in response to requests for variances from the closed-cycle cooling requirements now imposed at Indian Point, Bowline, and Roseton. Further hearings on Indian Point 2 and 3 before the AEC's successor agency, the Nuclear Regulatory Commission, are likely to be requested by the company on the basis of new evidence.

THE OPERATION OF THE EXPANDED MANDATE AND THE CONSULTATION AND REFERRAL SCHEME

Agency Unwillingness To Accept the Expanded Mandate

None of the three agencies involved in the expanded mandate reviews under the Federal Power Act or NEPA willingly undertook to effectively fulfill its expanded mandate on the issue of the estuarine fishery. The Court of Appeals has twice sent the Storm King case back to the FPC for full and proper investigation of the fishery. The AEC undertook the analysis of the fishery at Indian Point only after it was ordered to do so by the Court of Appeals for the District of Columbia Circuit in Calvert Cliffs' Coordinating Committee v. AEC.[37] The Corps of Engineers undertook the review of Roseton and Bowline only in settlement of suits brought by HRFA.

It may be argued that this is only the difficulty of initial compliance with broad mandates. I believe the trouble lies deeper. The FPC had had its mandate for many years before the 1965 decision. Even EPA which should be most willing to take a broad look at environmental issues has shown itself unwilling to comply with the Act in areas such as granting funds for waste treatment facility construction.[38] Numerous federal agencies have attempted to delegate their NEPA responsibilities to others, frequently those in state government.[39]

The recipients of federal grants or licenses have little interest in pressing the government to comply fully with the terms of the expanded mandate. This has meant that the only effective force for assuring full compliance has been public groups who would be protected by operation of the mandate and who are willing to exert pressure on the agency. I see no reason to think that this will not continue to be true.

The Lack of Agency Expertise To Comply With Expanded Mandate

None of the three agencies reviewed here, the FPC, the AEC, or the Corps of Engineers, had within its line staff the expertise to analyze properly the estuarine biological system. This may be less frequently true for small projects, say the filling of an acre of wetland for which a Corps permit is necessary, but is likely to be the normal circumstance for many large projects producing significant and widespread effects across complex estuarine systems.

In each of the cases reviewed, the agency turned to groups outside its own line staff to analyze the problem presented to it. The FPC turned to the Hudson River Policy Committee, which was drawn from the federal and state agencies with responsibility for fishery matters. The Corps of Engineers turned to an outside private consultant to review the impact of the two fossil fuel plants, and further built consultation with the Interior Department into the license terms for the two plants, stating that the Secretary of the Army would rely on the Secretary of the Interior to recommend measures which should be taken to protect the fish and wildlife of the Hudson River.[40] The AEC turned to the Oak Ridge National Laboratory for its analysis of the plant's impact on the river. Oak Ridge was, of course, part of the AEC, but not under the same regime as the regulatory staff, so that the regulatory branch of the Commission had to apply to the research arm for this NEPA work.[41]

It is evident that there is no internal repository of analytic strength or developed policy to which most agencies with an expanded mandate can turn. This is made clear by the fact that each agency turned to different sources to obtain expertise. From the product produced in each case, it is equally evident that there are highly variable levels of ability among the experts to whom the agencies turned.

This situation makes the results of operation under the expanded mandate very uneven. Another result is that when opposing private groups such as Con Edison and HRFA have litigated the same essential issues more than once, they tend to be more informed than the experts to whom the government agency turns, so that the "experts" are being educated by the partisans. To a certain extent, such education is good and proper, but the agency should have within its own organization or easily accessible to it impartial sources of expertise to which it can turn for aid.

Realistically, no agency is likely to have the full range of expertise inhouse that is needed for full and effective estuarine review. It is therefore essential that institutions modeled on the national laboratories be established with a special estuarine mandate to provide to relevant agencies the expertise needed for these analyses. Such institutions should be able to retain high quality personnel by offering a mix of research opportunities with analytic and semi-regulatory responsibilities. Only this mechanism will provide the agencies with expertise necessary for the effective discharge of their responsibilities.

Failure of the Consultation and Referral Mechanism

In the licensing proceedings reviewed, both NEPA and the Fish and Wildlife Coordination Act required the agency granting the license to consult with other agencies and groups with relevant expertise and jurisdiction. NEPA requires consultation with a wide spectrum of groups and interests. The Fish and Wildlife Coordination Act requires consultation with the Fish and Wildlife Service in the Department of the Interior, the National Oceanic and Atmospheric Administration in the Department of Commerce, and state agencies concerned with wildlife protection. The review here will focus on these federal and state agencies with fish and wildlife responsibilities.

Before the FPC's 1970 licensing of Storm King, all these agencies played an important role through their participation on the Hudson River Policy Committee, but in the remanded hearings in 1974, that position has shifted. The Interior Department is participating in the hearings and there is a task group of Interior and Commerce experts working on an analysis of the plant's possible impact. But the successor to the Hudson River Policy Committee, the Hudson River Fish and Wildlife Management Cooperative, has publicly declined to take a significant part in the hearings.[42] This is so despite the fact that the cooperative is made up of representatives of the Division of Fish and Wildlife and the Division of Marine and Coastal Resources in the New York Department of Environmental Conservation, the New Jersey Division of Fish, Game and Shellfisheries, the U.S. Bureau of Sport Fisheries and Wildlife, and the National Marine Fisheries Service, and has as its stated objectives to:

1. Coordinate evaluation of environmental impacts on fish and wildlife resources of the estuary and formulate appropriate response.
2. Develop a comprehensive fish and wildlife management plan for species of interstate significance.
3. Encourage implementation of the comprehensive plan by the agencies with primary responsibility.[43]

Thus the group which on paper should provide major guidance on fishery issues has chosen not to do so in the context of proceedings whose outcome may affect the fishery.

In the AEC and Corps of Engineers proceeding, the Interior Department submitted letters commenting on both impact statements.[44] The Corps' initial draft impact statement on Bowline in 1971 gave no indication that the plant could have serious impact on the fishery; Interior's letter did not disagree with that position.[45] The AEC's draft statement on Indian Point indicated the possibility of substantial damage to the fishery, though not the level of impact predicted in the final statement. Interior wrote the AEC a strenuous letter advocating the use of a closed-cycle cooling system.[46] The Department of Commerce did not submit anything substantial in response to either impact statement.[47]

Left to themselves, Interior and Commerce have largely reacted to what the other agencies have put before them. Where the work of the referring agency has been thorough and competent, the response under the Fish and Wildlife Coordination Act has been pointed and helpful. Where the referring agency's work has been second rate, the Coordination Act response is little better except in those cases which are the focus of public attention; then, as in the 1974 Storm King hearings, a special effort is made by the departments.

This is not an impressive record, but it is only fair to point out that the agencies are now staffed and funded to about one-half of what they and General Accounting Office believe is necessary for the effective operation of the Coordination Act.[48] This appears to be the fault of the executive branch in not requesting sufficient funds from Congress.[49] We will not really know whether this system can work properly unless it is adequately staffed and funded.

In addition to sufficient funding, Interior and Commerce will need an organizational format with an ongoing comprehensive view of estuarine systems and their wildlife. I can see no basic reason why this obvious organizational method of dealing with the Coordination Act responsibilities should not be achieved, but it has not yet been done.[50]

The State of New York has primary responsibility for the Hudson fishery, but it has not demonstrated the ability to develop its own articulated position on the fishery or to critique fully the positions put forward by others.[50A] The Department of Environmental Conservation (DEC) has primary responsibility for fishery management, but it has not produced a basic fishery management policy for the estuary. The state has the typical array of limitations on catch sizes, nets, meshs, and open seasons;[51] but these regulations are not drawn together into a policy which reflects any clear opinion on the life cycle or population dynamics of the striped bass or most of the rest of the estuarine fishery. This may be in part the product of history, since in New York in the past, the emphasis has been on the cold water fishery and the marine commercial fishery with little attention focused on the estuarine zone.[52] The net result is that the DEC has taken a back seat in determining the course of development which can affect the fishery. The department was represented on the Hudson River Policy Committee in the 1970 licensing of the Storm King plant, but as part of the Hudson River Management Cooperative, it has declined to take part in the analysis of fishery issues in the present remand. Before the AEC, the DEC was represented through the New York State Atomic Energy Council, but neither presented evidence nor took a position on the fishery issues before the licensing board. Its role before the Army Corps of Engineers has been equally passive.[53]

Unfortunately, New York's record of fishery management is reasonably typical of the performance of other states[54] and perhaps the fishery management profession generally.[55] It would not be a wise policy for the Congress to rely on the states to develop sound policies for the protection of estuarine productivity. These circumstances underscore the importance of full staffing and funding of Interior and Commerce's fish and wildlife agencies and the provision of expert assistance to the agencies with the expanded mandates.

Unequal Distribution of Resources

At least in the case of large projects, the resources brought to bear in licensing proceedings are very unequally distributed. The industrial or developmental interests are willing and able to devote hundreds of thousands, even millions, of dollars to procuring a license or permit to exploit estuarine resources. Citizens' groups have budgets which at best run in the tens of thousands and are dependent on pro bono or reduced fee help from lawyers and scientists. The governmental agencies expend sums which lie somewhere between industry and the private groups, but all too often closer to the private groups.

Con Edison is now spending approximately $3 million a year over a 5-year period on biological research alone on the Hudson.[56] Other utilities are contributing their share, and these sums do not include attorneys' fees or the other costs of applying for and obtaining a license. Congressional documents show that utilities now budget $500,000 to $1,000,000 for major nuclear licensings.[57]

Next to these massive sums, government expenditures appear puny indeed. The present Fish and Wildlife Service budget for all Coordination Act programs for the entire country is $7.5 million.[58] The Corps of Engineers was willing to pay consultants only $75,000 for a NEPA impact analysis to cover two fossil fuel plants on the Hudson.[59] Since applicants for permits take on most of the primary research, some greater expenditure on their part is to be expected. But these figures indicate utterly disproportionate spending.

The resources of citizens' groups representing public interests are even more scanty. The average intervention in an AEC proceeding costs $50–60,000.[60] Few groups can raise sums of this magnitude. On the Hudson, groups like HRFA and Scenic Hudson have existed on tiny annual budgets with the help of pro bono legal and scientific assistance.

Congress has increasingly encouraged citizen participation in environmental enforcement by, for instance, providing citizen suit provisions and allowing the payment of reasonable attorney and expert witness fees in such suits under the Clean Air Act and the Federal Water Pollution Control Act Amendments of 1972.[61] To be effective, this policy should extend more widely to proceedings before administrative agencies as well. It is there that facts on environmental issues are increasingly tried out and thus where the major expenses of litigation occur as well as where the terms of discretionary decisions are hammered out. It has generally been conceded that if our system of justice is to operate effectively, there must be a rough equality of resources on both sides of an argument. We must move closer to seeing that such equality is the fact as well as the ideal.

DISCUSSION AND RECOMMENDATIONS

The legal regulation of estuaries operates primarily through administrative agencies which have direct jurisdiction over part but not all of the estuarine system or its resources. The federal agencies typically operate through an expanded mandate requiring them to consider all the resources of the estuary and the effects of their actions on the entire system. Coupled to this expanded mandate is a system of consultation and referral putting particular emphasis on expert advice and recommendations from agencies with expertise and responsibilities which are focused on particular resources in the estuarine system such as fish and wildlife.

The record of effective regulation under this system has not been good for four primary institutional reasons: (1) the agencies are reluctant to fulfill their expanded mandate and frequently do so only under pressure from the public; (2) the agencies frequently do not possess the expertise to fulfill the mandate and rarely have an effective and impartial government source to which to turn for aid; (3) the federal referral agencies are understaffed and underfunded and thus are incapable of effectively dispatching their responsibilities, and the state agencies have a poor record of performance which does not hold much promise for future improvement; and (4) the resources brought to the decisionmaking process are overwhelming favorable to the private industrial and developmental interests and thus they tend to dominate both the governmental and public interest input to the process.

To make the system work effectively, there must be an evening of resources, so that the major interests—governmental, industrial, and public—are properly balanced. This should be achieved by taking three measures:

1. Within the discretion of the agency, groups representing public interests should be able to obtain reasonable attorney and expert witness fees in agency proceedings where they have contributed to the development and resolution of the issues before the agency. A model for such a provision exists in Title V of the Senate version of the Energy Research and Development Act of 1974[62] and should be adopted for all federal acts dealing with estuarine development and regulation. This will answer, in part, problems 1 and 4 set out above.

2. Congress should establish three or four National Estuarine Laboratories. Effective research and analytical support must be made available to the regulatory agencies on a continuing basis from institutions which develop expertise on entire estuarine systems and are required to present positions on proposed projects. The regulatory agencies cannot be entirely dependent on the presentation and analysis of facts by outside parties and what they need from within the government is much more than ad hoc consultation on particular projects under pressure for quick analysis. There must be a form of advocacy laboratory which engages in broad analysis and research so that it is readily familiar with major estuarine systems and produces an articulated program for protecting the estuary's productive capacity. Such a program would be able to put the individual and cumulative impacts of development in context from the viewpoint of the entire estuarine system and thus overcome some of the disadvantage of dispersed governmental authority. This would, in part, answer problems 1, 2, and 4 set out above.

3. The federal referral agencies under the consulation mechanism must be fully funded and staffed, and organized so that they maintain ongoing knowledge and expertise on entire estuarine systems. The General Accounting Office has already reported this need to Congress in the case of the Fish and Wildlife Coordination Act, and it is recognized as essential by the agencies affected. Action must be taken to put it into effect. This is the only course of action by which we will be able to test whether this system is or is not effective in providing protection to estuarine resources and productivity. This would, in part, answer problems 3 and 4 set out above.

FOOTNOTES

[1] 33 U.S.C. §1251(a).

[2] Delaware River Basin Compact, N.Y. Environmental Conservation Law §21-0701, et. seq. See Ackerman & Sawyer, "Uncertain Search for Environmental Policy: Scientific Factfinding and Decisionmaking along the Delaware River," 120 U. Pa. L. Rev. 419 (1972).

[3] 42 U.S.C. §1962(b), Executive Order No. 1137, 32 Fed. Reg. 12903 (1967) as amended.

[4] Power, "Chesapeake Bay in Legal Perspective," U.S. Department of the Interior, Federal Water Pollution Control Administration, Estuarine Pollution Study Series—1 (1970); personal communication with author.

[5] 42 U.S.C. §4321 et. seq. The terms of the National Environmental Policy Act are so well known that extensive description seems unnecessary, but a brief outline of the expanded mandate aspect may be useful. The Act requires that each federal agency in considering any project which would significantly affect the quality of the human environment and which the agency itself would undertake or which it can license or permit a private party to undertake must prepare a full statement on the impact of the project on the environment. 42 U.S.C. §4332. The Act instructs federal agencies, inter alia, to:

> preserve important historic, cultural, and natural aspects of our natural heritage, and maintain, wherever possible, an environment which supports diversity and variety of individual choice; [and] . . . achieve a balance between population and resource use which will permit high standards of living and a wide sharing of life's amenities. 42 U.S.C. §4321(b).

This is to be achieved "consistent with other essential considerations of national policy." Id.

While making environmental protection a part of the mandate of each agency, the Act provides for a system of careful analysis rather than a particularized policy of protection:

> Thus the general substantive policy of the Act is a flexible one. It leaves room for a responsible exercise of discretion and may not require particular results in particular problematic instances.
> . . . NEPA mandates a rather finely tuned and 'systematic' balancing analysis in each instance. *Calvert Cliffs' Coordinating Committee v. AEC*, 449 F.2d 1109, 1113 (D.C. Cir. 1971).

[6] Scenic Hudson Preservation Conference v. Federal Power Commission, 354 F.2d 608 (2d Cir. 1965), cert. denied, 384 U.S. 941 (1966).

[7] 40 U.S.C. §461 as amended by the Housing and Community Development Act of 1974, Sec. 401(b), (k), 88 Stat. 687–689.

[8] 33 U.S.C. §1251 et seq.

[9] 12 Me. Rev. Stat. Ann. tit. 12 §§4701–4709 (Rev. 1964, Supp. 1972); 38 Me. Rev. Stat. Ann. §§481–488 (Supp. 1972); N.H. Rev. Stat. Ann. §483-A (Supp. 1971); Mass. Gen. Stat. Ch. 130, §27a (Supp. 1971); R.I. Gen. Laws Ann. §11-46-1.1 (Supp. 1971); Conn. Gen. Stat. §§22a–28 to 22a–34; N.Y. ECL. §§25-0101 et seq. (McKinney 1973); N.J. Stat. Ann. §13:9A-1 to -10 (Supp. 1971); 7 Del. Code Ann. Ch. 70, §§7001 et seq.; Md. Ann. Code Art. 66C, §§718-31 (Supp. 1970); Va. Code Ann. §§62.1-13.1 to 13.20 (Supp. 1972); N.C. Gen. Stat. §113.229 et seq., (Supp. 1971); S.C. Code Ann. §§70-13 to -42 (Supp. 1973); Ga. Code Ann. §§45-136-147 (Supp. 1972); Fla. Stat. Ann. §§253.122–123 (Supp. 1972).

[10] 16 U.S.C. §1451 et seq.

[11] 16 U.S.C. §661 et seq.

[12] Hunt, A Historical Sketch of the Town of Clermont, Hudson (1928).

[13] State of New York Conservation Department, "A Biological Survey of the Lower Hudson Watershed," 15 (1937).

[14] Id.; Hudson River Policy Committee, "Hudson River Fisheries Investigation 1965–1968" (undated) (hereafter HRFI).

[15] U.S. Atomic Energy Commission, Directorate of Licensing, Final Environmental Statement, Indian Point Nuclear Generating Plant Unit No. 2, Sept. 1972 at V-40 (hereafter "IP2 FES"); Clark, "Effects of Indian Point Units 1 and 2 on Hudson River Aquatic Life," October 30, 1972 in transcript of In re Consolidated Edison Company of New York, Inc. (Indian Point 2) AEC Docket 50-247, following Tr. 6276, at 5-6 (hereafter "IPS Tr. at ——").

[16] 1 IP2 FES XII-29 to XII-35; Raney, "The Striped Bass, *Morone saxatilis*, of the Atlantic Coast of the United States with Particular Reference to the Population Found in the Hudson River," October 30, 1972, IP2 Tr. following 6254.

[17] 1 IP2 FES V-56.

[18] Testimony of C. Phillip Goodyear, IP2 Tr. at 9068–9071.

[19] In re: Consolidated Edison Company of New York, Inc. (Indian Point 2) RAI-73-9 751 (1973).

[20] Chittenden, "Status of the Striped Bass, *Morone saxatilis*, in the Delaware River," 12 Ches. Sci 131-36 (1971); Goodyear, "Origin of the Striped Bass Stock of the Middle Atlantic Coast," March 1, 1973, IP2 Tr. following 9858.

[21] Turner & Chadwick, "Distribution and Abundance of young-of-the-year striped bass, *Morone saxatilis*, in relation to river flow in the Sacramento-San Joaquin Estuary," 101 Trans. Am. Fish. Soc. 442–452 (1972); Clark, "Effects of Indian Point" at 54, IP2 Tr. following 6276.

[22] Temporary State Commission on the Water Supply Needs of Southeastern New York, "Water for Tomorrow," (1973). See N.Y. Times, March 15, 1975 at 29, col. 8.

[23] F.P.C. Opinion No. 584 (August 19, 1970).

[24] HRFI at 40; Affidavit of John P. Lawler, FPC Proj. No. 2338 (Jan. 16, 1974).

[25] 354 F.2d 608 (2d Cir. 1965), cert. denied, 384 U.S. 941 (1966).

[26] 16 U.S.C. §803(a).

[27] HRFI at 4.

[28] Id. at 4-5.

[29] Id. at 45.

[30] Scenic Hudson Preservation Conference v. FPC, 453 F.2d 463 (2d Cir. 1971), cert. denied, 407 U.S. 926 (1972).

[31] IP2 FES.

[32] In re Consolidated Edison Company of New York, Inc. (Indian Point 2), RAI-74-4 323.

[33] Hudson River Fishermen's Association v. Orange & Rockland Utilities, 72 Civ. 5460 (S.D.N.Y. 1972); Hudson River Fishermen's Association v. Central Hudson Gas & Electric Co., 72 Civ. 5459 (S.D.N.Y. 1972).

[34] Id.

[35] Id.

[36] Hudson River Fishermen's Association v. FPC, 498 F.2d 827 (2d Cir. 1974).

[37] 449 F.2d 1109 (D.C. Cir. 1971).

[38] See Urban Systems Research and Engineering, Inc., "Interceptor Sewers and Suburban Sprawl; The Impact of Construction Grants on Residential Land Use" (prepared for Council on Environmental Quality, 1974).

[39] E.g., Greene County Planning Board v. FPC, 455 F.2d 412 (2d Cir. 1972); Conservation Society of Southern Vermont v. Secretary, -F.2d-, 7 ERC 1236 (2d Cir. 1974).

[40] E.g., Letter of James W. Barnett, District Engineer to Central Hudson Gas & Electric Corp., 20 Dec. 1971, para. (W).

[41] Under Congress's new division of the AEC, national labs and the regulatory staff will be separated, the labs going into the Energy Research and Development Administration and the Regulatory Staff into the Nuclear Regulatory Commission.

[42] Letter of Herbert E. Doig to Kenneth F. Plumb, August 16, 1974 (Ex. 83A in 1974 hearings on FPC Proj. No. 2338).

[43] The Hudson River Fish and Wildlife Management Cooperative, Nov. 1973.

[44] 2 IP2 FES 45; Letter of Richard E. Griffith to Mark Abelson, April 28, 1971.

[45] Id.

[46] 2 IP2 FES 45.

[47] 2 IP2 FES 11.

[48] "Improved Federal Efforts Needed to Equally Consider Wildlife Conservation With Other Features of Water Resource Developments," GAO Report B-118370; Hearings Before the Subcommittee on Fish and Wildlife Conservation and the Environment of the Committee on Merchant Marine and Fisheries (93rd Cong., 2d Sess.) on GAO Report B-118370 and H.R. 42, H.R. 2285, H.R. 2288, H. R. 2291, H.R. 2292, H.R. 10651, and H.R. 14527 (Serial No. 93-33) ("Coordination Act Hearings") at 591, 600–605.

[49] Id. at 121-601.

[50] Two other federally established programs which might give backup support have also failed to provide technical assistance or a clear policy guidance. Congress gave its consent in 1940 to an interstate compact of the Atlantic coastal states for the joint regulation of the coastal fishery which clearly would encompass the estuarine dependent fishery (16 U.S.C. §367a), but the Atlantic States Marine Fisheries Commission established under the compact has not provided the technical analysis which would relate the production of estuaries to the coastal stock and thus the Commission has been unable to provide aid in determining the effect on the coastal fishery of development in the estuaries. Nor has the Department of the Interior used its statutory authority for Atlantic coast fishery studies to meet this need in relation to the Hudson. 16 U.S.C. §760a.

[50A] McHugh, "Marine Fisheries of New York State," 70 Fishery Bulletin 585 (1972); Ginter, "Marine Fisheries Conservation in New York State: Policy and Practice of Marine Fisheries Management," NYS Sea Grant Program, 1974 (NYSSGP-SS-74-012).

[51] 6 N.Y.C.R.R. Part 36; N.Y. Environmental Conservation Law §11-1511.

[52] Personal communication, James L. Biggane, formerly Commissioner, N.Y. Department of Environmental Conservation.

[53] In recent years, the New York Attorney General's office has moved to fill the vacuum and develop a state fishery policy through presentations before agencies and courts. Before the AEC, the attorney general took an active role generally supporting the position of the Oak Ridge staff, though no witnesses were presented. In the latest round of hearings before the FPC, the attorney general has been active and apparently plans to present witnesses as well as cross-examine those of other parties. The office also commented on the impact statement circulated by the Corps on the Bowline plant. In addition, the attorney general has brought a public nuisance suit against Consolidated Edison for fish destruction at the Indian Point plant. See Hudson River Fishermen's Association v. Consolidated Edison, N.Y. Law. Jour., June 6, 1971 at 2. This route for pursuing a fishery policy faces two important restraints. First, there are limited technical resources directly available to the attorney general, and it is unlikely that his office can develop the staff of fishery biologists, hydrologists, and computer experts needed for continuing analysis of the river. Second, the mandate of the attorney general does not extend to operating a management program for the estuarine fishery, so that a fully articulated program is unlikely to emerge from this effort.

[54] Remarks of J. L. McHugh at EPA Conference on Estuary Pollution Control, Feb. 11–13, 1975.

[55] Larkin, "A Confidential Memorandum on Fisheries Science," World Fisheries Policy: A Multidisciplinary View (Rothschild ed. 1972) 189.

[56] Consolidated Edison Company of New York, Inc., "Summary of Hudson River Research Programs, Approximate Cost of Ecological Studies" (Nov. 19, 1974).

[57] 120 Cong. Rec. S18724 (Oct. 10, 1974).

[58] Coordination Act Hearings at 591.

[59] Note 35, supra.

[60] 120 Cong. Rec. S18725 (Oct. 10, 1974).

[61] 42 U.S.C. §1857h-2; 33 U.S.C. §1365.

[62] 120 Cong. Rec. S18724 et seq.

ESTUARINE MANAGEMENT—THE INTERGOVERNMENTAL DIMENSION

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ABSTRACT

This paper provides a synoptic overview of the principal existing and pending federal laws and policies affecting the management of the nation's estuaries and estuarine zones. Specific attention is given to the influence these laws and policies have on the active management of such resources at the state, regional, and local levels. Using this analysis, the adequacy of extant federal policies to achieve established national goals and objectives on the preservation and conservation of estuarine resources is assessed. Finally, from this analysis current issues are identified, and proposed recommendations are made for federal policies to more adequately provide an institutional and management framework to protect these vital resources.

THE CURRENT SITUATION

The national government's concern and interest in protecting estuarine resources is relatively new. But the recognition that estuarine zones are productive and indispensable natural resources evolved only after many estuarine areas were lost to development and others imperiled.

During the decade of the 1960's dramatic growth and development experienced in the coastal states resulted in significant reduction of wetlands and the deterioration of some of our most valuable estuarine resources. The threat to these productive natural resources provoked legislative action in many coastal states and in Congress.

The first successful attempt to exercise a state's police power to protect estuarine resource systems came in Massachusetts with the enactment of that state's wetland legislation in 1963.[1] This statute requires a state permit as a condition to any significant alteration of coastal wetlands. It recognizes that these wetland areas are a natural resource held in trust for the people of the state, and usually a permit will not be issued if the proposed alteration would significantly damage estuarine and marine fisheries. The legitimacy of state regulation in these privately held areas was upheld by the Massachusetts courts.[2] The success of the Massachusetts law fostered enactment of similar statutes in many other coastal states. These state wetland laws were followed in a few states with a more comprehensive approach to coastal and estuarine management. Delaware,[3] Maine,[4] and California[5] are among the states that passed coastal zone management or conservation law.

Concurrent with many of these incipient state actions there was a national focus on oceanography. The Stratton Commission between 1967 and 1968 through its publication of "Our Nation And The Sea" [6] developed a greater federal and state awareness of the problems and opportunities in managing our coastal and ocean resources. The Stratton Report engendered a significant congressional interest in the vulnerability of the nation's coastal zone. The manifest congressional concern in estuarine resources was largely caused by this study, and culminated in the enactment of the so-called Estuary Protection Act of 1968 (P.L. 90-454). The Act provided for a study of the nation's estuaries, especially to determine if a "national system of estuaries" should be established. It also called for as national policy the protection, conservation, and restoration of the nation's estuaries, but in a manner that would maintain a balance between national needs for protection and conservation and the development of these estuaries to further growth and development. Moreover, the Act also asserts that the states have the basic responsibility for protecting the nation's estuarine resources.

In accordance with the mandate of the Act, the Department of the Interior issued a report in 1970 entitled "The National Estuary Study." This study, accomplished largely through outside consultants' contracts, examined the scientific, economic, governmental, and legal issues on the protection and management of estuarine resources. No specific legislative proposal emanated from the study, however.

Even without additional congressional policy on the protection of estuarine resources, other legislative and administrative actions began to influence the decisions involving development within these zones. The late 1960's brought an evolving environmental ethic within the federal establishment. The administration of the permit programs under the River and Harbors Act of 1899 (33 U.S.C. 403) by the Department of Army is a case study on this point.

Section 10 of this old statute prohibits the unauthorized obstruction or alteration of any navigable water of the United States. The Corps of Engineers had traditionally issued permits under the Act unless the proposal would interfere with navigation. However, the need to administer this legislation in accordance with contemporary environmental values caused a departure from this myopic approach. The vindication of this new federal environmental concern came in 1970 in the case of Zabel v. Tabb.[7] This litigation was brought after the District Engineer denied a Section 10 permit to fill 11 acres of tidelands in Boca Ciega Bay, Fla., on the grounds that the fill would be harmful to fish and wildlife. The 5th U.S. Circuit Court of Appeals held that the Corps of Engineers had properly taken conservation and environmental factors into account as well as navigational considerations. This holding was based on the Fish and Wildlife Coordination Act of 1959 (FWCA) and the National Environmental Policy Act of 1969 (NEPA). These statutes require consideration by federal agencies of environmental considerations other than missions assigned to them by their respective laws. The Supreme Court declined to review the case thereby letting the court of appeals' decision stand.

However, the general environmental impact analysis approach required under NEPA and FWCA were not considered adequate substitutes for substantive environmental policy. Congress recognized that impact assessments would not be adequate in areas requiring active resource planning and management.

Other Federal Legislation Relevant to Estuarine Management

The Senate and House Interior Committees did not follow up the "National Estuary Study" with proposed new legislation on protecting estuarine areas. But this was probably not associated with the merits of the study. Rather, the more likely reason for the absence of new estuarine legislation was the nature of the complex and overlapping committee structures in Congress. Several congressional committees exercise jurisdiction over legislation dealing with coastal and marine affairs. Quite independent of the activities in the Interior committees, these other committees were developing other legislative thrusts which happened to also directly affect the nation's estuarine zones.

Two such efforts culminated in 1972. The Senate and House Public Works Committees developed a major new water quality program in the Federal Water Pollution Central Amendment of 1972 (P.L. 92-500). This legislation protects estuarine resources in several ways. It requires the states to establish, under federal criteria, ambient water quality standards and effluent limitations. Compliance with these standards is obtained through a permit program encompassing all discharges into navigable waters. Areas having substantial water quality problems are required to develop continuous water quality management planning and programming processes under Section 208 of the Act. Such management planning must consider land use, curtailment of non-point sources, and, where appropriate, methods to control saltwater intrusion caused by curtailment of freshwater flow. Probably, the most important aspect of the statute on estuarine resources is the law's water quality goals for 1983. By that date, the nation's waters should provide for the protection and propagation of fish, shellfish and wildlife, and recreation in and on the water. Consequently, the Act establishes one absolute parameter for protecting and managing the estuarine zones.

On the other hand, the Coastal Zone Management Act of 1972 has a comprehensive rather than single purpose environmental orientation. It originated in the Senate Commerce and House Merchant Marine and Fisheries Committees. This law authorized the Secretary of Commerce to make grants to coastal states in planning for and administering sound management programs for the coastal zone. Its basic approach is that decisionmaking on the use of the coastal zone, which by definition encompasses the estuarine zone, is basically a state prerogative subject to the overriding national interest in such areas as water quality standards, navigation, deepwater ports, and the production of energy. To achieve this objective of state primacy, the legislation encouraged the establishment of a management process including an intergovernmental system to achieve wise use of land and water resources of the coastal zone. One of the principal inducements for the state to develop an unified management program for the areas is that, when approved, the state management process will subject the federal government's actions to stringent consistency checks against adopted state policies. Under Section 307, application for a federal grant, license or permit to conduct activities affecting land water uses in the state's coastal zone must be consistent with the state's approved coastal management program. Normally, direct federal government activities must also be consistent with the state program.

The Act also recognizes the particular value of preserving estuarine resources. Under Section 312, the Secretary is authorized to make grants up to 50 percent of the cost of acquiring and operating estuarine sanctuaries for the purpose of creating natural field laboratories to study the natural and human processes within estuaries.

In 1972, Congress also enacted the Marine Protection, Research and Sanctuaries Act of 1972 (P.L. 92-532). The Act mainly affects ocean resources. But it also will assist in the protection of the waters within estuarine zones. This results from two programs provided for in the legislation. Section 103 requires the Secretary of the Army to issue permits for the transportation of dredged material for the purpose of dumping it in ocean waters. No such permit may be issued, however, if the Administrator of EPA finds that the dumping of such material will result in an unacceptable adverse impact on shellfish beds, fisheries, wildlife, or recreational areas. Moreover, the protection of estuarine areas will be assisted also under the authority in Section 302 of the Act. This provision vests the power in the Secretary of Commerce, after consultation with other federal agencies and with approval of the President, to designate as marine sanctuaries those areas of ocean or coastal waters which he determines necessary to preserve or restore such areas for their conservation, recreational, ecological, or aesthetic values. Once designated, the Secretary must issue regulations to control any activities within such areas, and federal activities can only be undertaken in these sanctuaries if the Secretary certifies that they are consistent with the management of the area as a marine sanctuary.

Finally, a summary of the existing environmental policies affecting the protection of estuaries, or any other important natural resource, would not be complete without including the National Environmental Policy Act of 1969 (P.L. 91-190). This far-reaching statute declares it the national policy to encourage a productive and enjoyable harmony between man and his environment. To assure that this policy is incorporated into all the programs and actions of the federal government, Section 102 of the Act directs that to the greatest extent possible the policies, regulations, and public laws of the United States shall be interpreted and administered to reflect the purposes of the Act. This section also mandates all federal agencies to prepare detailed environmental impact statements on major federal actions significantly affecting the quality of the human environment. Such statements are to insure that environmental amentities and values will be given appropriate consideration in federal decision-making processes.

While NEPA does not establish absolute environmental standards, it provides the integrative force to focus all appropriate environmental policies and values on major federal programs and regulatory systems.

Proposed Federal Legislation

The national energy crisis is becoming an important new factor in protecting estuarine resources. To become more self-sufficient, additional energy sources are being sought. One of the prime areas for new oil exploration is in the Outer Continental Shelf. But exploration for new energy sources is not the only approach contemplated to meet the problem. For example, coastal and estuarine areas are attractive locations for new power plants, especially nuclear facilities.

In response to those needs, the Department of Interior has indicated that areas in the Baltimore Canyon area of the Continental Shelf adjacent to the states of New Jersey, Maryland, Delaware, and Virginia will be opened to oil exploration in 1975. Existing production areas will be subject to more intense exploration activities. As a result, the Administration has requested and Congress has appropriated supplemental funds for FY 1975 to accelerate the coastal state planning efforts to prepare for the impact of these energy-inspired activities in the offshore areas. These monies will be available to the coastal states under the Coastal Zone Management Act of 1972.

Congress has also evinced interest and concern over the potential environmental consequences of new energy development activities. For example, the Senate has established the National Ocean Policy Study Group in the Commerce Committee.[8] In April 1974, the Committee received testimony on the potential impact of Outer Continental Shelf oil and gas development along the Atlantic, Pacific, and Gulf of Alaska. Much of the testimony recognized that the nearshore areas of the coastal zone would absorb a major part of the environmental impact. One federal official cited the impact of offshore drilling in the Gulf of Mexico as evidencing that these activities would cause loss of wetlands and affect circulation conditions of nearshore areas.[9]

These and other congressional hearings have generated a plethora of bills dealing with the environmental consequences of development in the continental shelf area.[10] One of these measures was enacted in the last days of the 93rd Congress—Deepwater Port Act of 1974 (P.L. 93-627). In the main, the Act authorized the Secretary of Transportation upon application to issue, transfer, and renew 20-

year licenses for the ownership, construction, and operation of deepwater ports in waters beyond the territorial limits of the United States. This legislation is simply a recognition by the executive branch and Congress that new domestic energy sources are not the immediate answer to our problem. Rather, oil imports will continue and the United States must have adequate facilities to accommodate the ever-increasing fleet of supertankers. Again, as in the case of new offshore exploration, any such legislation will inevitably have significant impact on estuarine areas, albeit of a more localized nature.

Impact of Federal Law and Policy on Estuarine Management Act State and Substate Level

Most of the federal legislation discussed above affecting estuarine areas have a single thrust; they encourage states to develop balanced management processes for such areas. The Estuary Protection Act and the Coastal Zone Management Act represent this policy. In the former case the legislation has had little impact in generating state management policies for wetland and estuarine areas. Its most important contribution has been to perpetuate continuing congressional interest in estuarine problems and, to some extent, cause federal agencies to consider state policies relative to the management of these resources. A good example of the latter is the Corps of Engineers' use of the Act as the basis for considering state policy and the administration of its permit programs concerning activities in navigable ocean waters.[11]

On the other hand, the Coastal Zone Management Act has had widespread impact on estuarine management. It appears that all coastal and Great Lake states will participate in the program. This will have direct implications on estuarine management. The Act and its implementing regulations require each participating state to evolve over a period not to exceed three years a unified coastal zone management program, together with a coordinated administrative system for its implementation. Thus the Act supports a substantial increase in state law and authority in the estuarine zone.[12] The program must identify important coastal resource areas such as estuarine zones. It must insure that such resources are encompassed in the state's defined coastal zone. Further, discreet policies must be adopted for their protection, conservation, and development. The defined coastal zone also must include upland areas necessary to control uses of land which have a direct and significant impact on coastal waters.

To insure adequate implementation of the management program, and to resolve conflicts of competing uses, each participating state must have a technique to control land and water uses in the coastal zone. Although several options are available, most states will probably establish standards and criteria for implementation by local governments. Many states also intend to use regional planning agencies to assist in implementing the program.

As pointed out above, the program is not mandatory. States are encouraged to participate and receive two-thirds of the cost of developing a coastal management program. Such development grants can be made annually for three years. After that period a state may only receive annual grants toward the cost of administering its program if the Secretary of Commerce approves the program. A principal inducement for securing program approval is that subsequently the federal government must generally conduct its programs and activities in accordance with the approved state management program.

Already the coastal management program is having significant impact on state, regional, and local governments. If most coastal states remain in the program, state and local government will be making explicit planning and policy-based decisions on the future use of estuarine resources. Most importantly, however, such decisions will be made within the framework of a coastal management process which will weigh environmental as well as economic and social values. It must be reiterated that the importance given estuarine resources in this process is essentially a state value judgment. Unless there is a preemptive national policy, as in the case of the Federal Water Pollution legislation, the state's perception of estuarine management must prevail.

The Federal Water Pollution Control Act of 1972 had the most immediate impact on the management of estuarine resources at the state and local levels. Prior to this Act, federal policies dealing with water quality impacts on estuarine waters and coastal wetlands were diffuse and ambiguous. But the Act provided definitive standards and goals which encompassed all of the nation's navigable waters. Currently, EPA and the Corps of Engineers' regulations involving the various permit programs under the Water Act and the Refuse Act extend federal water quality standards into wetland areas. Therefore, federal or state permits for any alteration in wetland areas must now be evaluated in the terms of their effect on water quality. The application of the water quality standards in these areas by EPA has been upheld by the United States District Court in Florida.[13]

The NEPA has also fostered the consideration of related federal environmental policies in these permit programs. As indicated above, for example, the Corps of Engineers' regulations on permits for activities in navigable waters or ocean waters under the Refuse Act and the Marine Protection Act require consideration of the proposed activity on wetlands and the estuarine zone.[14] In the former case, the federal policy on wetlands has been administratively derived, and in the latter the implications on estuarine management reflect the general policies in the Estuary Protection Act. But there is little doubt that the integration of these related environmental policies was brought about largely through the mandate in NEPA.

ESTUARINE MANAGEMENT— THE FEDERAL POLICY ISSUES

No single federal policy focuses on developing new initiatives to protect the nation's estuarine areas. This lack of central responsibility does not indicate absence of congressional or federal executive concern, however. Indeed, there is no paucity of federal law and administrative regulations pertaining to these resources. On this point some would suggest the federal presence in these areas is already too large. Congress apparently does not share this view. If they did, the continuing requirement to study these areas such as that contained in Section 104(n) of the Federal Water Pollution Control Act would not be necessary. Rather, it can be argued that the central national concern is the need to evaluate the adequacy of existing estuarine policy, and to do so as a part of a critical examination to determine the appropriate federal role. The ancillary issues emanating from this proposition are discussed below.

For the purpose of analysis, current federal policy affecting estuarine resources can be fitted into three basic categories.

The first may be described in terms of actual federal acquisition of estuarine resources. Under congressional authorization, the Department of Interior has acquired areas of particular national interest. Typically, they are wilderness areas or areas suitable for recreational use. Many estuarine areas are contained in this national parks system. But they represent a small segment of our total estuarine resources.

The second category of this federal policy involves regulatory and coordinative efforts. With the exception of the Estuary Protection Act and administratively established policies on wetlands, these programs only have incidental application to estuarine zones. Their main purpose is to protect some other natural resource value, e.g., Fish and Wildlife Coordination Act.

The last category involves encouraging states to develop comprehensive resource management programs. Of course, the Coastal Zone Management Act is the most relevant to estuarine management in this regard.

As indicated above, these disparate policies reflect the structure of Congress and the federal executive branch. There is no single locus in the system which has the exclusive responsibility for natural resource management. Consequently, the various executive agencies sharing responsibility coordinate their efforts through informal or ad hoc interagency mechanisms. This can be a positive exercise, but too often agency mission and interest make it difficult for such peer groups to arrive at balanced or comprehensive decisions. As a result, there is no central or uniform federal executive policy on the protection of the nation's estuarine resources. Moreover, the National Environmental Policy Act does not adequately fill this gap. It does cause federal grant and regulatory decisionmakers to consider the totality of federal environmental policy when arriving at decisions affecting estuarine resources. In this process only congressionally-mandated environmental standards, e.g., water and air quality standards, are absolute, however. All other environmental factors are subjectively weighed by the federal agency entrusted with the final decisionmaking authority. In such a coordinative management process policies of state and local government on estuarine management are often critical. Both the Estuary Protection and the Coastal Zone Management Act require federal agencies in making decisions affecting estuarine resources to comply with state policies if they are not in conflict with the national interest.

Based on the above survey of current federal policies on protecting estuarine resources, the following major issues have been identified:

- *Will the federal incentives to encourage states to develop coastal zone management programs result in adequate state and local government programs for the protection or prudent use of estuarine resources?*

The initial response by the state is salutary. The real test will come, however, when they propose coastal management programs for approval by the Secretary of Commerce. At that time a determination must be made from a national perspective on whether the several states have identified estuarine areas as areas of particular concern, with appropriate managerial constraints placed on their use, including related land uses.

- *Are there adequate federal policies to insure that development encroaching on estuarine areas will be adequately managed by state and local governments to protect the estuarine resources?*

The Coastal Zone Management Act goes a long way toward achieving this result. It has certain geographical constraints, however. A state's coastal zone may only include inland areas necessary to control uses which have a direct and significant impact on coastal waters. This boundary may be adequate in most cases to protect estuarine areas. However, in densely populated metropolitan regions the pressures of development in the areas immediately adjacent to the coastal zone may exert pressures which ultimately result in development in the zone itself. This void could have been filled if national land use legislation had been enacted. In its absence, other approaches must be sought. This will necessitate close coordination among federal agencies having complementary programs affecting state and local government land use policies. The comprehensive planning grant assistance program[15] administered by the Department of Housing and Urban Development and EPA's area-wide water quality management planning program[16] will influence land use decisions in the areas adjacent to the coastal zone.

• *Is the administratively established policy on wetlands adequate to protect estuarine resources?*

Presently, federal policies on wetlands have been derived without an explicit congressional mandate. And they have become important considerations in making federal regulatory and development decisions within these areas, especially in those states which do not presently have adequate wetland protection policies. However, as administrative policy they do not have the same standing as legislation. This makes the application of these policies particularly vulnerable in cases where the only potential constraint on a proposed activity is the federal wetland policy itself.

• *Are current federal policies for the protection of estuarine areas adequate to ameliorate impending development pressures caused by the impact of oil and gas exploration in the Outer Continental shelf to meet the energy crisis?*

This is probably the most serious national challenge to the preservation of our estuarine areas. Since the federal government has exclusive control in the development of OCS resources, the states are vulnerable to the impact of such activities. Advanced and joint federal-state planning for the onshore impacts is vital. The proposed federal planning grant funds for this purpose will assist in minimizing potential adverse effects on coastal and estuarine resources. If adverse environmental impact from such exploration and other energy development activities is to be minimized, however, additional federal impact assistance to coastal states will be required.

RECOMMENDATIONS

In responding to the aforementioned issues the following recommendations are offered:

• A federal interdepartmental estuarine task force should be established, probably as an adjunct to the federal coordination responsibilities of the Department of Commerce in the administration of the Coastal Zone Management Act. This group would be charged with: 1) identifying existing federal laws and policies affecting estuarine management and synthesizing them into unified federal policy for uniform application throughout the federal establishment; 2) developing objective evaluation criteria to determine the adequacy of state programs and regulatory policies on the protection and use of estuarine resources, including related land uses; and 3) examining the current administratively established federal wetland policies, and preparing and recommending to Congress a legislative program for wetland protection to be applicable to all federal grant-in-aids and regulatory programs, as well as direct federal management and development activities.

• Develop legislation to provide federal impact aid funds to coastal states. These federal funds should be available to minimize adverse environmental effects and control associated social impacts caused by the development of energy resources in the coastal zone and Outer Continental Shelf. Such grants should be conditioned on advance planning and programming for these impacts under the Coastal Zone Management Act. The acquisition of lands, construction of public facilities, and the provision of public services within the impact coastal areas should be eligible activities under this program.

FOOTNOTES

[1] Chapter 130-Section 27A as amended, Massachusetts General Laws.

[2] Commissioner of Natural Resources v. S. Volpe & Co., 349 Mass. 104, 206 N.E. 2d 666 (1965).

[3] Delaware Coastal Zone Act of 1971, 7 Del. Code Ch. 70, 7001, et seq.

[4] Maine Site Location Act, 38 M.R.S.A. 481–488 (1970).

[5] California Coastal Zone Conservation Act of 1972, Public Resources Code, 27000 et seq.

[6] Julius A. Stratton, Chairman, Commission on Marine Science, Engineering and Resources established by P.L. 89-454. The Commission published as its final report Our Nation and the Sea, and three panel reports.

[7] Zabel v. Tabb, 430 F.2d 199 (5th Cir. 1970).

8 Senate Resolution 222 established in the Senate Commerce Committee the National Ocean Policy Study Group.

9 Robert M. White, Administrator, National Oceanic and Atmospheric Administration, Department of Commerce, in a prepared statement before the National Ocean Policy Study Group, Senate Commerce Committee, April 23, 1974.

10 e.g., S. 3221, Energy Supply Act of 1974; S. 2858 Outer Continental Shelf Safety Act of 1974; S. 2672, Marine Resources and Conservation Act of 1974; S. 5, Deepwater Port Act of 1974, all introduced in the 93rd Congress.

11 Disposal of Dredged Material in Navigable and Ocean Waters, 33 C.F.R. 209, 145.

12 Specific indications of the growth in state law and authority can be found in the Office of Coastal Zone Management's State Coastal Zone Management Activities—1974, and Bradley and Armstrong, A Description and Analysis of Coastal Zone and Shoreland Management Programs in the United States, March 1972.

13 United States v. Holland, 4 ELR 20710 (M.D. Fla., Mar. 27, 1974).

14 Supra, Note II.

15 Section 701, Housing Act of 1954, as amended.

16 Section 208, Federal Water Pollution Control Act Amendment of 1972 (P.L. 92-500).

BASIC FACTORS OF POPULATION DISTRIBUTION AFFECTING DEMAND FOR WATER RESOURCES

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ABSTRACT

The number of people is not the critical factor in water pollution, but the way the population is distributed and the life patterns that are followed. This report describes the changing distribution of the population of the estuarine counties of the eastern seaboard including the development of new urban structures such as the megalopolis and the creation of new lifestyles brought about by increased leisure time, retirement, second homes, commuting, female participation in the labor force, and changing residential arrangements.

INTRODUCTION

Evidence is accumulating that water will be the focus of a great world environmental crisis of the future. The pressures of very rapid population growth, industrialization, and improvements in the levels of living will be followed by a steadily increasing consumption of water. A result will be pressures for a more complete utilization of existing water resources everywhere.

Widely publicized food shortages have resulted from a serious drought in many countries since 1972. Some climatic experts insist that the world may be entering into a new cycle of drought that may last for a number of years. The reaction to predicted lack of precipitation will be development of wells and dams that permit irrigation of large tracts of land; such a step could have serious ramifications for both the quantity and even more importantly, the quality of water.

In the United States these pressures will most likely result in an acceleration in the use of water in the estuaries of the eastern seaboard; a subsequent deterioration of these water resources is quite likely unless preventive action is taken in the immediate future. The possible deterioration of water resources is related to the changing life patterns of the human population, patterns that can bring immense changes in the environment.

Already the almost solid configuration of cities and industry along most of the northern portion of the eastern seaboard has resulted in widespread pollution of the estuaries. The limited concentrations of population and industrial developments have spared much of the southern coastal areas from these problems.

Acknowledging that problems of pollution are manmade, it is appropriate to analyze the changing distribution of the population along the eastern seaboard and to ascertain some of the trends in American life that affect the water resources.

The basic theme of this report is that the mere number of people is not the critical factor in the water pollution of a given area, but rather, the way in which the human population is distributed. Above all, the life patterns of mankind determine the impact he has upon his environment. Thus, there are two major sections to this analysis: First, a description of the changes that are taking place in the distribution of the population, especially along the east coast; and second, some of the changes in the life patterns of the American population, especially demographic trends, which have relevance to the relationship of the human population to the natural environment.

The logic of this approach to understanding water pollution is demonstrated by the following definition agreed to at a Geneva conference in 1961, "a water is considered polluted when its composition or state is directly or indirectly modified by human activity to the extent that it is less suited for purposes it could have served in its natural state" (Furon, 1967:105).

Although technically the definition may be inadequate, one has but to glance at a few of the myriad products of human behavior which do pollute the water of the world—pesticides, fertilizers, industrial effluents, raw sewage, synthetic detergents, and household refuse—to realize that the problem is widespread and serious (Furon, 1967:106–108).

GENERAL TRENDS IN POPULATION DISTRIBUTION

At the time of the first census of the United States in 1790, the population of the country was 3,929,214, largely restricted to a narrow band along the east coast. The rate of growth per decade ran over 30 percent from 1790 until 1880 with the exception of the 10-year period from 1860 to 1870. In this era of the Civil War the growth rate remained high, amounting to 22.6 percent. Although after 1880 the decennial rate of growth started declining, it was still 25.5 percent between 1880 and 1890.

The 100 years between 1790 and 1890 witnessed the westward movement of the population until settlement was virtually complete from the east to the west coast. The population of the nation increased manyfold after 1790 and stood at 62,979,766 when the census was taken in 1890.

This westward movement, the Civil War, and changing agriculture brought the abandonment of many farms and plantations along the eastern seaboard. Rice production completely disappeared from Georgia and South Carolina. The chain of islands along the coastal areas of the south at one time had large cotton plantations when water was the principal medium of transportation. The fields were permitted to become fallow and forests were soon soon established as the population shifted to the mainland.

At the beginning of the 19th century, the United States was basically a nation of agriculturists. Only 5 percent of the country's population resided in cities when the census was taken in 1790. Around a decade later the growth of cities became an all pervasive phenomenon, not only in the United States, but the rest of the world as well. In 1850, 15.3 percent of the population of the nation lived in cities, but by 1900, the figure had increased to 39.6 percent. Some theorists have associated the growth of the cities with the development of the railroad as a major means of transportation. By 1920, 51.2 percent of the inhabitants of the United States lived in cities. These cities were largely constructed about the intersection of railroads or where they terminated at ocean ports.

With the advent of the automobile, the stage was set for a modification in the urbanization process. Increasingly, people could reside farther and farther into the suburbs and still work in the central business district. The growth of cities continued until in 1940, 56.5 percent of the nation's population resided in urban areas, that is, population centers with over 2,500 inhabitants.

Accelerating since the 1940's was a second urban revolution—the rapid decentralization of cities. The metropolitan region became the focus of human existence. Practically all of the hundreds of modern shopping centers that dot the American landscape on the periphery of the major cities have been constructed since World War II. A concomitant of this decentralization has been the loss of function by the central business district; the decay of these inner cities was widely publicized during the 1960's. Nevertheless, the urban population, including the suburbs adjacent to the major urban centers, continued to grow. In 1970, nearly three out of four American citizens (73.5 percent) were classified as urban.

A third revolution in the growth of cities, an urban sprawl, seems underway (Gottman and Harper, 1967). The largest urban areas of the United States are now starting to lose population. Between 1960 and 1970, 15 of the 21 cities in the United States with populations above 500,000 in 1960 actually lost population. More recent estimates indicate that this trend is accelerating and that a very large percentage of the major cities of the nation will lose population during the decade of the seventies, at the same time the urbanized portion of metropolitan areas tends to spread over the countryside.

At the same time, it needs to be emphasized that the population of the nation continues to grow rapidly, reaching 213,000,000 during the fall of 1975. Ours remains essentially an urban population with people living on the fringes of the larger cities in an ever-widening radius. This fringe development has been a major phenomenon of recent years and is likely to continue. On the other hand, the probability that the central cities will experience rebirth and renewed population growth is remote.

The cities of the United States have grown largely through young people abandoning the farms for life in the cities. This rural to urban migration was a major factor in the redistribution of the population over the last 150 years. This migration was enhanced by the immigration of thousands upon thousands of foreign born during the late 19th and early 20th centuries. There were several years in which over a million immigrants came to the United States, settling generally in the central core of the larger cities. Currently, the effect of immigration on the growth of central cities has declined because immigration proceeds at a slower rate than previously, and because the modern immigrant tends to join relatives who may be scattered throughout the nation, rather than in the urban ghettos.

Even more important for the growth of cities is that the rural-farm population base is so small. Only 5.2 percent of the nation's inhabitants lived on farms in 1970. The birth rates of the rural farm residents are declining to a level comparable to those of the rest of the nation's citizens. Cities simply cannot depend upon a continuation of the in-migration of a surplus rural population as a source of growth. Urban growth must come from a natural increase.

In spite of the fact that the population of the nation is increasing rapidly, it is obvious that all sections are not equally sharing this growth. Of the 3,124 counties and county equivalents in the United States, about one-half actually lost population between 1960 and 1970, a decade in which the total population increased by nearly 24,000,000. Less than one-third of these counties grew through immigration.

The greatly reduced birth rates of the seventies means that rapid growth for an area must be sustained by internal migration. The redistribution of the population draws an increasing portion of the population away from the vast midlands of the continent to the coastal areas (See Figure 1) (Ullman, 1954), although the coastal counties of the southern United States have not experienced rapid growth through internal migration in recent years.

"The only areas of the country in which more than half the total population increase was due to net immigration were Florida, the coastal portions of the Pacific Northwest, and California. Collectively, these three areas had a net inflow of more than 4 million persons in the 1960's, whereas the remainder of the country had a net migration loss of nearly 1 million" (U.S. Bureau of the Census, 1974:129).

These trends in the redistribution of the population are especially important for those concerned with changes along the seaboard of this nation. The population, for example, in the coastal counties of the eastern seaboard contained 16.7 percent of the total population of the nation in 1950. This percentage has slowly but steadily increased to 17.1 percent in 1960, 17.4 percent in 1970, and the latest population estimates as of July 1, 1973 show that 17.5 percent of the nation's population lives in these counties. (See Table 1). The total population of these coastal and estuarine counties has increased from 25,283,811 in 1950, to 36,921,600 in 1973. Another way to look at the tendency of the population to live in coastal areas is that this band of seaboard counties experienced a 21.8 percent increase between 1950 and 1960. At the same time the population of the nation as a whole was increasing 18.6 percent. During the next decade these coastal counties increased 15.6 percent compared with an increase of 13.5 percent in the total population of the United States. The latest estimates show that between 1970 and 1973 these estuarine counties increased 3.8 percent while the nation's population increased 3.0 percent.

Many people have become aware recently that the nation's birth rates have fallen to the lowest point in history. A real possibility exists that population increase in the nation may fall below the replacement level within the next very few years, especially if economic conditions worsen. At the present time the crude birth rate is about 14.8 per thousand and the death rate is 9.2 per thousand. As the average age of the population increases, it is inevitable that the death rate will rise. If the birth rate continues the decline that started in 1957 and rapidly accelerated about 1965, there will be a balance between births and deaths within, perhaps, the next 15 years.

A reduction in the rate of growth or even a period in which the population of the nation reaches stability does not mean that the number of residents in the coastal counties will reach an equilibrium. In fact, trends point to further rapid population growth in the estuarine areas almost independent of what occurs to the total population of the nation.

NEW URBAN STRUCTURES

The growth of cities covers a much wider range of developments than is often recognized. Most people in the United States have a stereotyped image of the city based on the concentric zone model in which the central business district is surrounded by low income housing and industrial activities. As one moves out from this center toward the suburbs the quality and spaciousness of the homes improves. Growth is thought of as occurring in concentric rings as the population continues to move out from the center in all directions.

Actually the city has taken many forms in human history. What we tend to think of as a city in the United States is basically a product of the 19th century when the urban structure was based upon aggregations of industry at a major railway center. By contrast, the cities of antiquity did not have the central business districts characteristic of this country. The nucleus of the city does not always have a commercial function. The center of the city may be either a religious shrine, a political center, or a university.

We may anticipate that the American city of the future will have a much different structure than is common at present. One indicator of this change

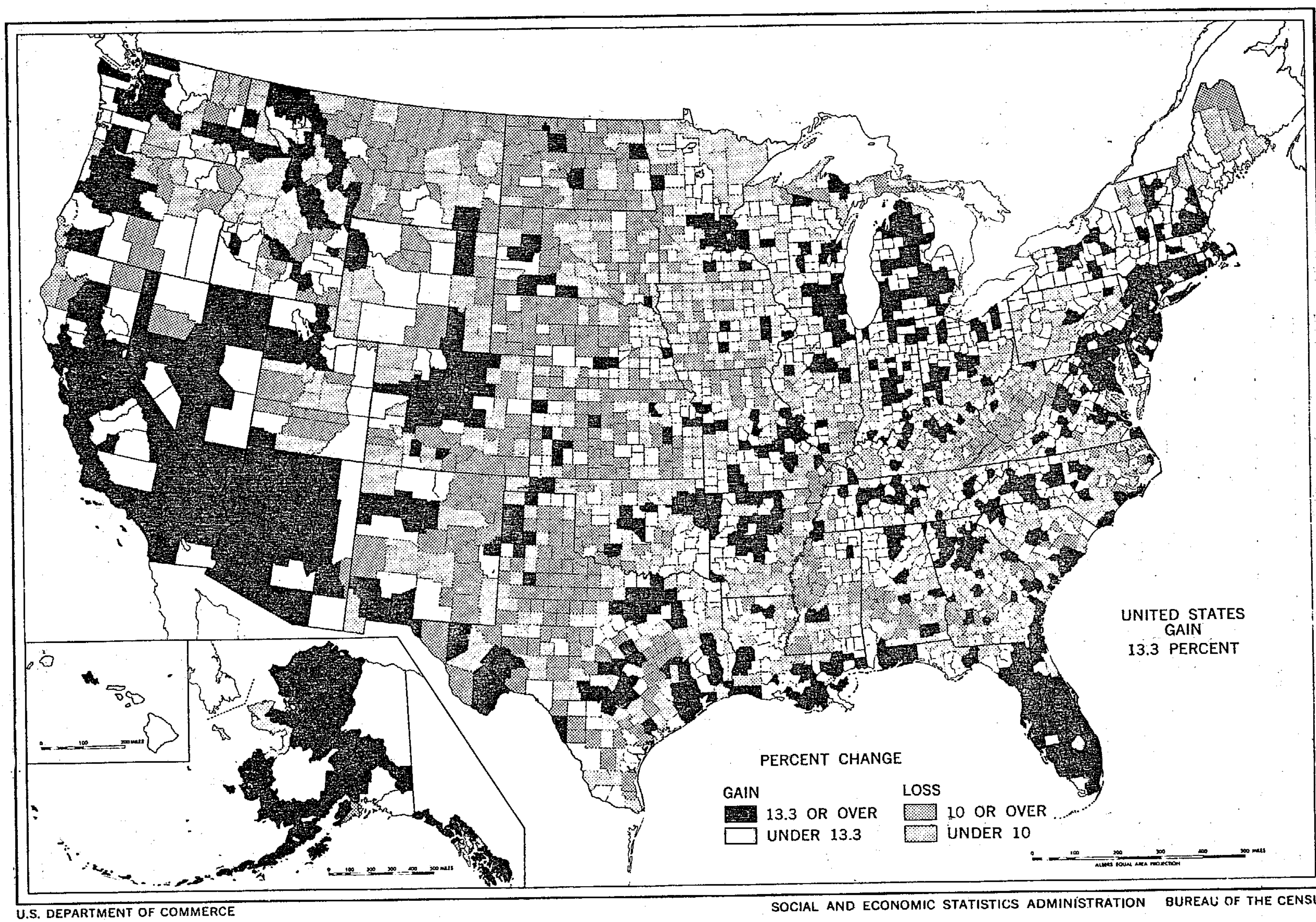


FIGURE 1.—Percent of change in total population by counties: 1960 to 1970.

Table 1.—Total population of estuarine counties of the Eastern Seaboard, 1950–1973.

	1950	1960	1970	1973
MAINE				
Cumberland	169,201	182,751	192,528	197,200
Hancock	32,105	32,293	34,590	37,000
Knox	28,121	28,575	29,013	31,100
Lincoln	18,004	18,497	20,537	21,600
Sagadahoc	20,911	22,793	23,452	24,900
Waldo	21,687	22,632	23,328	25,500
Washington	35,187	32,908	29,859	31,200
York	93,541	99,402	111,576	117,600
TOTAL	418,757	439,851	464,883	486,100
NEW HAMPSHIRE				
Rockingham	70,059	99,029	138,951	153,700
TOTAL	70,059	99,029	138,951	153,700
MASSACHUSETTS				
Barnstable	46,805	70,286	96,656	109,000
Bristol	381,569	398,488	444,301	461,300
Dukes	5,633	5,829	6,117	6,900
Essex	522,384	568,831	637,887	647,400
Nantucket	3,484	3,559	3,774	4,200
Norfolk	392,308	510,256	604,854	614,300
Plymouth	189,468	248,449	333,314	364,700
Suffolk	896,615	791,329	735,190	734,700
TOTAL	2,438,266	2,597,027	2,862,093	2,942,500
RHODE ISLAND				
Bristol	29,079	37,146	45,937	46,100
Kent	77,763	112,619	142,382	148,700
Newport	61,539	81,891	94,228	99,700
Providence	574,973	568,778	581,470	586,300
Washington	48,542	59,054	85,706	92,200
TOTAL	791,896	859,488	949,723	973,000
CONNECTICUT				
Fairfield	504,342	654,589	792,814	787,800
Middlesex	67,332	88,865	115,018	121,000
New Haven	545,784	660,315	744,948	756,800
New London	144,821	185,745	230,654	239,800
TOTAL	1,262,279	1,588,514	1,883,434	1,905,400
NEW YORK				
Albany	239,386	272,926	286,742	288,700
Bronx	1,451,277	1,424,815	1,471,701	1,449,200
Columbia	43,182	47,322	51,519	55,900
Dutchess	136,781	176,008	222,295	229,700
Greene	28,745	31,372	33,136	37,200
Kings	2,738,175	2,627,319	2,602,012	2,507,100
Nassau	672,765	1,300,171	1,428,080	1,412,400
New York	1,960,101	1,698,281	1,539,233	1,463,800
Orange	152,255	183,734	221,657	233,600
Putnam	20,307	31,722	56,696	63,500
Queens	1,550,849	1,809,578	1,987,174	1,984,600
Rensselear	132,607	142,585	152,510	155,700
Richmond	191,555	221,991	295,443	312,000
Rockland	89,276	136,803	229,903	240,100
Suffolk	276,129	666,784	1,127,030	1,197,200
Ulster	92,621	118,804	141,241	151,600
Westchester	625,816	808,891	894,406	891,100
TOTAL	10,401,827	11,699,106	12,740,778	12,673,400

	1950	1960	1970	1973
NEW JERSEY				
Atlantic	132,399	160,880	175,043	185,100
Bergen	539,139	780,255	897,148	897,900
Burlington	135,910	224,499	323,132	323,500
Camden	300,743	392,035	456,291	474,200
Cape May	37,131	48,555	59,554	65,900
Cumberland	88,597	106,850	121,374	130,900
Essex	905,949	923,545	932,526	936,900
Gloucester	91,727	134,840	172,681	181,300
Hudson	647,437	610,734	607,839	617,700
Mercer	229,781	266,392	304,116	316,100
Middlesex	264,872	433,856	583,813	597,100
Monmouth	225,327	334,401	461,849	477,600
Ocean	56,622	108,241	208,470	250,000
Salem	49,508	58,711	60,346	62,300
Union	398,138	504,255	543,116	546,300
TOTAL	4,103,280	5,088,049	5,907,298	6,062,800
VIRGINIA				
Accomack	33,832	30,635	29,004	29,200
Arlington	135,449	163,401	174,284	163,800
Caroline	12,471	12,725	13,925	14,400
Charles City	4,676	5,492	6,158	6,600
Chesterfield	40,400	71,197	77,045	90,400
Dinwiddie	18,839	22,183	25,046	22,800
Essex	6,530	6,690	7,099	7,100
Fairfax	98,557	275,002	455,032	514,000
Franklin	24,560	25,925	28,163	29,600
Gloucester	10,343	11,919	14,059	115,600
Hanover	21,985	27,550	37,479	43,300
Henrico	57,340	117,339	154,364	165,300
Isle of Wight	14,906	17,164	18,285	18,700
James City	6,317	11,539	17,853	19,100
King and Queen	6,299	5,889	5,491	5,400
King George	6,710	7,243	8,039	8,500
King William	7,589	7,563	7,497	7,500
Lancaster	8,640	9,174	9,126	9,200
Loudoun	21,147	24,549	37,150	41,700
Mathews	7,148	7,121	7,168	7,800
Middlesex	6,715	6,319	6,295	6,500
Nansemond	25,238	31,366	35,166	----
New Kent	3,995	4,504	5,300	6,300
Norfolk	99,937	51,612	----	----
Northampton	17,300	16,966	14,442	15,300
Northumberland	10,012	10,185	9,239	9,100
Prince George	19,679	20,270	29,092	19,800
Princess Anne	42,277	76,124	----	----
Prince William	22,612	50,164	111,102	129,100
Richmond	6,189	6,375	6,504	6,300
Southampton	26,522	27,195	18,582	18,200
Spotsylvania	11,920	13,819	16,424	19,200
Stafford	11,902	16,876	24,587	27,900
Surry	6,220	6,220	5,882	6,260
Westmoreland	10,148	11,042	12,142	12,900
York	11,750	21,583	33,203	36,800
Independent Cities:				
Alexandria	61,787	91,023	110,927	105,000
Chesapeake	----	----	89,580	93,900
Colonial Heights	6,077	9,587	15,097	16,900
Fairfax	----	----	22,009	21,600
Falls Church	7,535	10,192	10,772	10,300
Franklin	----	----	6,880	6,700
Fredericksburg	12,158	13,639	14,450	15,400
Hampton	5,966	89,258	120,779	127,300
Hopewell	10,219	17,895	23,471	23,800
Newport News	42,358	113,662	138,177	137,500
Norfolk	----	----	307,951	283,100

Table 1.—Total population of estuarine counties of the Eastern Seaboard, 1950-1973.—(Continued)

	1950	1960	1970	1973
VIRGINIA—(Cont.)				
Petersburg	35,054	36,750	36,103	43,600
Portsmouth	80,039	114,773	110,963	109,100
Richmond	230,310	219,958	249,431	230,400
South Norfolk	10,434			
Suffolk	12,339	12,609	45,024	47,400
Virginia Beach		8,091	172,106	192,900
Williamsburg	6,735	6,832	9,069	10,200
TOTAL	1,397,165	1,975,189	2,942,965	3,008,700
MARYLAND				
Anne Arundel	117,392	206,634	298,042	321,700
Baltimore	270,273	492,428	620,409	637,500
Baltimore City	949,708	939,024	905,789	871,300
Calvert	12,100	15,826	20,682	23,700
Cecil	33,356	48,408	53,291	55,300
Charles	23,415	32,572	47,678	54,600
Dorchester	27,815	29,666	29,405	28,800
Harford	51,782	76,722	115,378	129,100
Kent	13,677	15,481	16,146	16,500
Prince Georges	194,182	357,395	661,087	695,000
Queen Annes	14,579	16,569	18,422	19,000
Saint Marys	29,111	38,915	47,388	49,000
Somerset	20,745	19,623	18,924	18,600
Talbot	19,428	21,578	23,682	24,800
Wicomico	39,641	49,050	54,236	56,900
Worcester	23,148	23,733	24,442	25,500
TOTAL	1,840,352	2,383,624	2,954,994	3,027,300
DELAWARE				
Kent	37,870	65,651	81,892	89,900
New Castle	218,879	307,446	385,856	400,000
Sussex	61,336	73,195	80,356	85,800
TOTAL	318,085	446,292	548,104	575,700
NORTH CAROLINA				
Beaufort	37,134	36,014	35,980	36,100
Bertie	26,439	24,350	20,528	20,300
Brunswick	19,238	20,278	24,223	29,800
Camden	5,223	5,598	5,453	55,600
Carteret	23,059	27,438	31,603	33,600
Chowan	12,540	11,729	10,764	10,600
Craven	48,823	58,773	62,554	67,000
Currituck	6,201	6,601	6,976	8,500
Dare	5,405	5,935	6,995	7,800
Gates	9,555	9,254	8,524	8,200
Hertford	21,453	22,718	23,529	22,500
Hyde	6,479	5,765	5,571	5,600

	1950	1960	1970	1973
NORTH CAROLINA—(Cont.)				
Martin	27,938	27,139	24,730	24,000
New Hanover	63,272	71,742	82,996	92,100
Onslow	42,047	86,208	103,126	94,200
Pamlico	9,993	9,850	9,467	9,400
Pasquotank	24,347	25,630	26,824	27,100
Pender	18,423	18,508	18,149	18,800
Perquimans	9,602	9,178	8,351	8,300
Pitt	63,789	69,942	73,900	73,500
Tyrrell	5,048	4,520	3,806	3,700
Washington	13,180	13,488	14,038	13,600
TOTAL	499,188	570,658	608,087	620,300
SOUTH CAROLINA				
Beaufort	26,993	44,187	51,136	54,900
Berkeley	30,251	38,196	56,199	58,200
Charleston	164,856	216,382	247,650	256,200
Colleton	28,242	27,816	27,622	28,300
Georgetown	31,762	34,798	33,500	35,400
Horry	59,820	68,247	69,992	79,000
Jasper	10,995	12,237	11,885	12,000
TOTAL	352,919	441,863	497,984	524,000
GEORGIA				
Bryan	5,965	6,226	6,539	7,300
Camden	7,322	9,975	11,334	12,000
Charlton	4,821	5,313	5,680	6,200
Chatham	151,481	188,299	187,816	179,700
Glynn	29,046	41,954	50,528	50,900
Liberty	8,444	14,487	17,569	17,700
McIntosh	6,008	6,364	7,371	8,200
TOTAL	213,087	272,618	286,837	282,000
FLORIDA				
Brevard	23,653	111,435	230,006	228,400
Broward	83,933	333,946	620,100	738,600
Dade	495,084	935,047	1,267,792	1,367,100
Duval	304,029	455,411	528,865	547,800
Flagler	3,367	4,566	4,454	5,400
Indian River	11,872	25,309	35,992	40,800
Martin	7,807	16,932	28,035	36,800
Nassau	12,811	17,189	20,626	24,400
Palm Beach	114,688	228,106	348,993	403,000
St. Johns	24,998	30,034	31,035	34,700
St. Lucie	20,180	39,294	50,836	57,700
Volusia	74,229	125,319	169,487	191,200
TOTAL	1,176,651	2,322,588	3,336,221	3,675,900

is that the central business district is rapidly declining in importance. Population, commercial activities, and industry have been decentralizing for several decades. The modern shopping centers which are so prevalent today did not come into existence until after the termination of World War II. Manufacturing has largely moved from the central city to new locations in the outskirts of metropolitan centers or even in isolated rural areas.

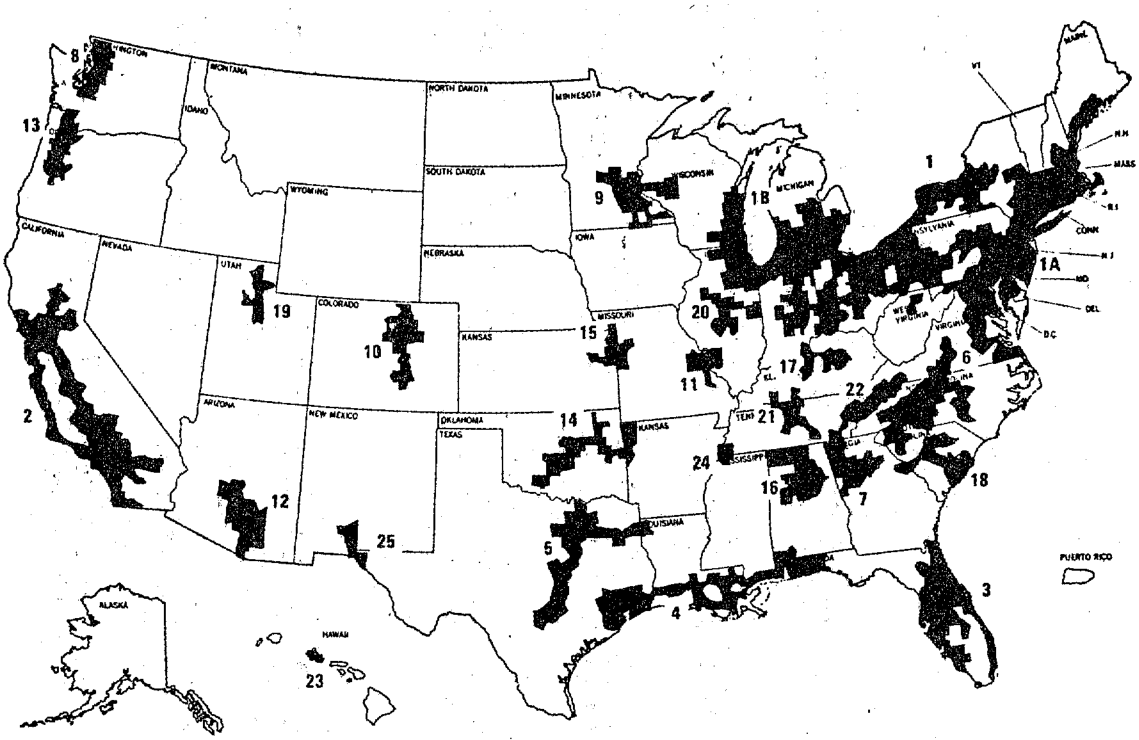
Two types of urban structures are evolving: One has as the main street the perimeter highway that connects a series of the major shopping centers. Over the last few years, large numbers of apartment complexes have come into existence near these perimeter highways. The other new main street of America is the interstate or other multi-lane expressway that stretches for hundreds of miles with attached nodes of residential development, manufacturing establishments, shopping centers, major recreational facilities, medical complexes, transportation centers, and the like, forming a strip city.

The most spectacular of this latter type is the megalopolis of the eastern seaboard that joins cities from New Hampshire to Virginia into an amazing urban complex. The scholar, Jean Gottmann, who popularized the concept Megalopolis in his book by this name stated that this new urban region brought rural and urban together into an integrated whole, "In this gradual symbiosis two seemingly conflicting trends have worked together: urban people and activities have taken on more rural aspects and traditionally rural pursuits have acquired urban characteristics. Some sectors of an urbanized region have come to look the way rural countryside used to while districts specializing in agricultural production have begun to resemble built-up suburbs. The whole pattern of land use has changed rapidly" (Gottmann, 1961:217).

More recently, another major megalopolis has come into existence along the east Florida coast that promises to incorporate the entire Florida peninsula. Today, a narrow band of urban development extends the length of the state from Miami to Jacksonville.

As yet largely unaffected by this trend have been the coastal areas of Georgia, South Carolina, and North Carolina. Projections of past trends in population growth do not indicate the urbanization of this section of the Atlantic coast. (See Figure 2). Yet, trends other than past population growth would indicate that the megalopolis of the northeast and that of Florida will eventually merge into a gigantic urban complex extending nearly 2,000 miles.

The availability of land, water, and a mild climate provide the basis for such a development. The final



1. Metropolitan Belt
   1.a. Atlantic Seaboard
   1.b. Lower Great Lakes
2. California Region
3. Florida Peninsula
4. Gulf Coast
5. East Central Texas—Red River
6. Southern Piedmont
7. North Georgia—South East Tennessee
8. Puget Sound
9. Twin Cities Region
10. Colorado Piedmont
11. Saint Louis
12. Metropolitan Arizona
13. Willamette Valley
14. Central Oklahoma—Arkansas Valley
15. Missouri—Kaw Valley
16. North Alabama
17. Blue Grass
18. Southern Coastal Plain
19. Salt Lake Valley
20. Central Illinois
21. Nashville Region
22. East Tennessee
23. Oahu Island
24. Memphis
25. El Paso—Ciudad Juárez

Based on 2-child family projection

FIGURE 2.—Urban regions: year 2000. Source: Pickard, 1972: 143.

catalyst may be the interstates and other expressways which fuse Florida and the northeast into a major main street of the United States.

The emergence of this new entity comes into sharper focus when one reflects that early in the present century before the appearance of the automobile, people fulfilled their needs for goods and services within walking distance of their homes. Homes were located near the place of employment in order that the journey to work could be minimal. Neighborhood schools, grocery stores, churches, plus the local physician made it possible for all to live a rather complete life without leaving the small community. The locality was a functioning social system to which individuals had a strong identity.

The pattern today is much different. Most residential areas have few, at times none, of the services demanded. People go to one locality for medical services, another to schools, still another for groceries, and perhaps a more distant location to purchase clothes, furniture, or an automobile. The automobile has become a necessary ingredient of daily life in the United States. An increasing percentage of the population has two or more automobiles that are continuously in use. The location of goods and services brings patterns of life in which each person tends to travel within an increasingly larger area. Outlook and use of space tends to be more regional than tied to a specific locality.

There are no strong loyalties to a given establishment and a new shopping center can rapidly disrupt existing patterns. Existing trade and service patterns are altered with the construction of modern highways. The interstate system is new and some portions are not complete in the South Atlantic coastal area. With the passage of time, factories, new stores, and services will locate along expressways. These establishments will inevitably provide so much competition that some more isolated businesses will be abandoned. The trend is for more people to spend more time on the highways in satisfying their daily needs.

CHANGING PROBLEMS OF WASTE DISPOSAL IN MEGALOPOLIS

The emerging megalopolis has made dysfunctional the political subdivisions that were largely created during the 19th century. The central city was considered the center of a region with its business nucleus as the "heart." A hierarchical web of relationships bound the metropolis, its suburbs, satellite towns, and rural hinterland into a functioning whole. Each part tended to have its own political identity (Gottmann, 1961:736). The division of responsibilities among state, county, cities, and other minor political subdivisions gave a system that rather effectively provided needed functions.

The unplanned, urban sprawl that has accompanied the development of megalopolis and other urban regions has resulted in one problem with which existing civil divisions were not prepared to cope: maintenance of a pure water source. The water supply depends upon cooperation across many political boundaries. Public health demands services that are increasingly difficult for political units based upon an old urban hierarchical structure to furnish. New collective solutions are needed in many areas but in none more important than the protection and utilization of water resources (Gottmann, 1961: 376–377).

An examination of the changing practices in the disposal of solid and liquid wastes reflects the need as urbanization progresses for political units that can provide collective means of household sanitation as a substitute for traditional, individualistic ones. Even today along the more sparsely populated sections of the South Atlantic States, it is necessary for individuals to fulfill sanitation needs on an individualistic basis. In the modern city a modern sewerage system safely disposes of large quantities of liquid and organic wastes. The periodic rounds of the garbage collector gives an easy way for individuals to discard waste papers, magazines, and a large variety of containers.

Historically, the situation was much different for the person living in isolation. Food wastes were fed to chickens, hogs, and other animals. Papers and other inflammable materials were burned. Tin cans, bottles, and other such materials were thrown into a family trash heap away from the house. Periodically, these latter materials were hauled away and dumped into streams, gullies, or flatlands draining into the estuaries. Human wastes were deposited in the old-fashioned privy or pit toilet. This system of sanitation was based on individual efforts. Even today, sewage lines, garbage collection routes, and the like are not economically feasible in a sparsely settled rural political subdivision with a small tax base.

The expansion of existing metropolitan areas and the growth of smaller population centers into cities forces collective solutions to sanitation problems. In the interim between individualistic and collective solutions, there is a period in which the risks of water pollution are very great. Isolated vacation homes along the beaches and estuaries create special problems. These clusters of homes have no collective solutions to sanitation problems. Often raw sewage is dumped directly into streams. Household trash is dumped into the edge of a stream to be carried off by the next tide. These practices are often continued in some sizeable towns and villages in spite of health regulations prohibiting such practices. A lone county sanitarian may not have sufficient political clout to stop such practices. Those reared in a rural milieu are accustomed to these traditional practices and do not view them as a threat to health and the environment. Also, many communities are inhabited by people with low incomes who do not have the financial resources to pay taxes sufficiently large to develop sanitary sewage or garbage collection systems. Consequently, these people are often content to continue with the present system.

Answers to questions about other solutions show that a large portion of these people living in isolation believe it would be an infringement on their freedom to have a collective system of waste disposal forced upon them, especially if such a system meant an increase in taxes or a charge for the service.

Collective solutions to many problems may be essential and can only be furnished by new political entities. Yet, individuals will resist the changes. For them, traditional solutions are deemed preferable. Others do not want to see civil subdivisions give up present function and responsibilities. Especially reluctant to see changes are those with a vested interest in the status quo.

The human value system does not necessarily welcome changes that are both needed and inevitable. The response applies to individuals, corporations, and industries.

NEW LIFE STYLES AND WATER POLLUTION

The changing urban structure is accompanied by many changes in lifestyles that can have a great impact upon the estuaries of the nation. In our affluent society there has been the widespread diffusion of many of the material conveniences of human life as the process of urbanization has developed. This affluency has been made possible by the industrialization of the United States and of many other countries. Full employment and economic prosperity have made it possible for automobiles, air conditioning, television, refrigerators, and many other appliances and manufactured products to be possessed by a very large percentage of the United States' population including those who are classed as living in poverty. Most live in houses with modern plumbing and fully-equipped kitchens that protect the family from the rigors of the elements.

Much more important than the simple possession of these material things is the way in which they are used. New lifestyles are coming into existence that affect man's relationship to the environment. A high protein diet, for example, based upon the consumption of beef results in much more land being used to provide food than was true in the past. The direct consumption of potatoes, wheat products, and other starches has steadily declined. Through the years automotive transportation has replaced pedestrian travel and public transportation.

Affluency has become so much a characteristic of American life that it has lost its status value. People today with much more leisure time than existed previously are adopting new lifestyles that have many of the attributes of an old agrarian society. These new lifestyles result in demands for beaches, vacation homes, extensive travel, backpacking, and other forms of outdoor recreation. Dining out and the search for other forms of recreation keeps large numbers of people on the highways.

A focus for many of these activities is along the estuaries of the eastern United States. Residents of the large metropolises throng to the more popular public recreational centers along the rivers, bays, and beaches. Extensive camping and other outdoor activities may destroy the ground cover. Campfires and the haphazard disposal of the debris by the participants of outdoor recreation litter the countrysides. Roads and trails for the increasingly popular four-wheeled vehicles, trail bikes, and dune buggies scar the land.

American society today seems possessed by a desire to escape from affluency and return increasingly to nature. The call to nature has resulted, at times, in the destruction of forests and protective dunes. The channelization of streams, the construction of roads and other recreational and vacation facilities have drastically altered the environment in many areas. Population growth is but one factor in the utilization of these natural resources. New lifestyles are placing new demands upon the natural resources. Obviously, any change in the environment of the drainage areas is going to have an impact upon the water in the estuaries (See Ronald G. Ridker, 1972: 17–33).

DEMOGRAPHIC FACTORS AND NEW LIFE STYLES

Not everybody in the United States follows the same lifestyle. Great differences exist between isolated rural areas, the ghettos of the large cities, retirement villages in Florida, and the suburbs of Connecticut. Even within a given community there may be several principal lifestyles followed by various segments of the population. Style of life may be considered as the way in which material possessions are used. These patterns of consumption vary among status groups in a community. For example, an automobile may be the source of livelihood for one group of the population, a means of transportation to work for another, and a vehicle for recreational purposes only for still another. These patterns of behavior tend to form configurations which are followed by all within a given group of the population.

During the 1950's there was the stereotype of the suburban family, a couple with four or five children, with its station wagon, residing in a split-level house. The lifestyle of this group would have been much different from that of the factory worker with a pleasure automobile, who took the bus to work while his wife stayed home in a crowded tenement dwelling.

A number of trends can be discerned from demographic and other data that are having a great impact upon the lifestyles in the United States. Some of these trends are developing more rapidly in the coastal areas than in other sections of the nation.

Leisure Time

One of the more important of these developments for the estuarine areas has been the shorter workweek for those in the labor force, resulting in more time for leisure. For more than a century man has increasingly had more of his day freed from economic pursuits which increases his opportunity to engage in recreational and other activities. The classic work describing this transition was published by Sebastian de Grazia in 1962 under the title, "Of Time, Work, and Leisure." De Grazia points out several changes that have reduced the time man spends in economic pursuits.

The first of these is that people in the United States enter the labor force at a later age than they previously did. In the past, adolescents of 12 or 14 often were full-time workers. Various labor laws and increasing years of education have resulted in people entering the labor force at an older age.

Second, changing customs and laws have resulted in people retiring at the age of perhaps 60 or 65. Retirement was almost unknown in the past. Today almost all workers may expect voluntary or involuntary retirement in their 60's. Further, increasing life expectancy in the United States has resulted in a much larger percentage of all people born eventually reaching the retirement age and having several years of life outside the labor force.

In addition to the delayed entry into the labor force and the withdrawal from it two other developments have occurred that give those in the active productive ages much more leisure time. The first of these is that most employers now make provision for vacations. The paid vacation is a relatively recent phenomenon. "As late as the 1920's only a small number of wage earners had paid vacations. Among salaried workers the paid vacation was more common" (De Grazia, 1964:59–60). Today, vacations, holidays, and sick leaves for the average worker are a fringe benefit that reduces the number of hours the average person works per year by at least 15 days.

Even more spectacular has been the decline in the number of hours that people work. De Grazia estimates that in 1859 the average agricultural worker put in 72 hours a week and those in non-agriculture industries 65.7 hours every week. After this date there have been steady declines in the number of hours that people work. By 1940 it was estimated that those in non-agriculture put in 54.6 hours. By 1960 these figures on the length of the average work week had dropped to 38.0 hours in non-agriculture and 44 in agriculture, an average of 38.5 for all workers (1962:420). The declines since this date have been more modest. It has been estimated that the average workweek had dropped to 37 in 1970. He projects it will further decline to 35 hours by 1980 (De Grazia, 1968:114).

These estimates are for the nation as a whole. The actual number of hours worked might differ somewhat in the eastern United States, but the trend is unmistakeable. People today have a greater percentage of their life outside the labor force and while employed work on the average much less than a generation or so ago. This shorter workweek provides a basis for new lifestyles that would not have been possible in the past when the average employee had little time for anything other than meals and sleeping in addition to his work. Free time for recreation was almost unknown. The activities of the entire family are influenced by this new work schedule which permits all members of the family to spend time outside the home.

Retirement

The lifestyles of retired people are much different from those of young adults. Generally, older people are more sedentary and consume less than those in the prime of life. Increasing life expectancy has resulted in a tremendous increase in the number of people above the age of 65 in the United States. In 1950 there were 12,397,000 people above the age of 65 representing 8.1 percent of the total population. This number increased dramatically to 19,972,000 in 1970 and to 21,815,000 as of July 1, 1974. Today 10.3 percent of the nation's inhabitants are above the age of 65 compared with 9.8 percent in 1970 and 9.2 percent in 1960.

Social security and other retirement plans provide a constant source of income for an increasing percentage of the elderly. Many of these individuals are migrating to coastal sections of the country considered to have a pleasant climate. The vicinity of St. Petersburg, Fla., is widely known as a retirement haven. Approximately 30 percent of the population of several counties in the vicinity of St. Petersburg is above the age of 65 years. Even more striking however, is that 48.8 percent of the Miami Beach population is above the age of 65. Other coastal cities of Florida also are the homes of many retired persons.

A special tabulation of the changing number of people above the age of 65 years residing in the estuarine counties, starting with Broward County, immediately north of Dade in which Miami is located, and extending to the Canadian border, shows a great increase in the number of elderly in recent years.

These coastal counties in 1950 had 2,082,463 residents above the age of 65, but by 1970 this number had increased to 3,569,388, a growth of 71.4 percent. By contrast, the increase in the number of elderly in the country as a whole was significantly less for the period, 61.1 percent.

Table 2 presents statistics on the changes in the number of old people in the eastern seaboard counties, by states. It may be noted that the rate of increase in the population above the age of 65 was below the national average in the coastal counties of Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut to the north, but only North Carolina among the more southern group of states. Most spectacular is the increase of over 400 percent in the selected Florida counties during this 20-year period.

The percentage of the total population of all the eastern seaboard counties above the age of 65 tends to be less than the national average. This finding is a consequence of a high influx of young people in a growing population and will change as those in the productive ages enter retirement, unless the total population continues to increase rapidly through the immigration of young workers.

The trend seems unmistakable for those with financial means to move to warmer coastal areas upon retirement. The small family pattern that has emerged in recent decades coupled with mobility of young people means that the family ties are not as likely to hold a person to the community in which he spent his productive years. Further, substantial growth in the number of people retiring to the southern estuarine counties may be expected. This migration will probably be more directed to larger communities with relatively complete medical and service facilities.

Table 2.—Population 65 years old and over in the estuarine counties of the Eastern Seaboard, 1950–1970

	1950 Number	%	1960 Number	%	1970 Number	%
Maine	47,163	11.2	53,695	12.2	57,849	12.4
New Hampshire	7,931	11.3	9,676	9.8	12,148	8.7
Massachusetts	279,477	11.5	299,850	11.5	334,058	11.7
Rhode Island	70,418	8.9	89,540	10.4	103,932	10.9
Connecticut	112,775	8.9	154,045	9.7	181,267	9.6
New York	823,932	7.9	1,162,666	9.9	1,388,261	11.4
New Jersey	323,957	7.9	461,088	9.0	572,136	9.7
Virginia	101,397	7.3	143,663	7.3	190,597	6.5
Maryland	140,950	7.6	171,749	7.2	128,183	4.3
Delaware	26,320	8.3	35,745	8.0	43,833	8.0
North Carolina	29,002	5.8	37,151	6.5	46,581	7.7
South Carolina	16,745	4.7	22,297	5.0	29,132	5.8
Georgia	12,353	5.8	17,278	6.3	22,329	7.8
Florida	90,043	7.7	234,382	10.0	459,082	13.8
TOTAL	2,082,463	8.2	2,892,824	9.4	3,569,388	10.0

Second Homes

A preoccupation with the growth of population has tended to detract attention from a number of extremely important demographic trends. One of these developments is the proclivity of Americans over the last few years to acquire a second home. These dwellings are generally in the more isolated rural areas where one can enjoy the beauties of nature. The construction of these houses often has very serious ramifications not just for the environment but the economic stability of an area. Often those constructing vacation homes are not restricted by any construction codes or by regulations for disposal of human wastes. Also, many are located in the submarginal areas that should be zoned for forestry or recreation with no residential construction permitted.

One of the most desirable locations for vacation homes in the minds of many people is along the beaches and the estuaries of the eastern seaboard. Of course, other individuals express a preference for the mountains. Regardless of the relative attraction of the mountains or the beaches, a large percentage of the population wants to escape at least periodically, from city life. Beach property has tended to advance manyfold in price during recent years. The increase in the cost of beach property is in itself an indication of growing demands for such sites for a second home.

A special report of the census reveals that 2.9 percent of families in the United States had a second

Table 3.—Second homes and seasonal housing units, estuarine counties of the Eastern Seaboard, 1970

	Occupied Housing Units			Seasonal Housing Units		
	Total Number	Number with Second Home	Percent with Second Home	Total Number	Percent of all Housing Units	State Total Units Held Occasional Use
Maine	146,635	15,672	10.7	35,431	17.6	6,486
New Hampshire	41,677	3,153	7.6	8,274	15.6	3,037
Massachusetts	901,766	56,960	6.3	43,218	4.3	11,611
Rhode Island	291,965	13,337	4.6	9,884	3.1	1,687
Connecticut	577,936	26,146	4.5	7,886	1.3	6,615
New York	4,232,501	189,763	4.5	51,846	1.2	58,186
New Jersey	1,836,689	85,240	4.6	70,506	3.6	21,490
Virginia	864,091	33,885	3.9	4,832	0.5	19,032
Maryland	883,615	28,169	3.2	12,494	1.3	7,974
Delaware	164,804	9,517	5.8	5,222	2.9	1,273
North Carolina	171,543	6,988	4.1	8,052	5.0	13,372
South Carolina	134,430	616,695	5.0	6,938	3.4	8,695
Georgia	86,189	3,764	4.4	509	0.5	12,154
Florida	1,123,478	63,794	5.7	19,389	1.5	46,561
TOTAL	11,457,319	543,083	4.7	284,481	6.2	218,173

home in 1967. This number increased dramatically during the next three years and the 1970 Census of Population reported that 2,890,000 families, or 4.6 percent of the total, had a second home in 1970. The construction of these second homes proceeded at a very rapid pace until about 1973 when the rate of construction declined. Many of these new second homes are a part of large developments in mountain and resort areas, but especially, in some of the more attractive beach areas. No accurate statistics are readily available on the extent of these recent developments.

One indication of the location of these second homes may be obtained from the Census of Housing. These reports show the number of homes in each county classed as seasonal. These figures underestimate the number of vacation homes inasmuch as the census has a separate category for the dwellings held of occasional use. The number in this latter category is not presented by counties. The number of seasonal homes in the estuarine counties (see Table 3) is therefore, the best index available of the location of second homes. Although admittedly incomplete, these statistics reflect the areas in which such dwellings are concentrated.

Two notable concentrations of such houses are in two counties of New Jersey. Cape May had 24,817 such structures and Ocean County had 29,851. Most of these dwellings are used by individuals residing outside the counties because only 1,254 of the families in Cape May reported owning a second home in 1970 and the figure for Ocean County was but 3,245. Another concentration is in Barnstable County, Mass., (Cape Cod) which reported 21,524 seasonal homes. Relatively few were reported for the coastal areas of Georgia, Virginia, North Carolina, and South Carolina. Nevertheless, it is known that several land developments have brought about such increases the last few years.

The percentage of the population of the estuarine counties with a second home is presented in Table 3. The proportion of the population owning a second home in these counties does not differ greatly from the national average, and is most pronounced in the most northern coastal states of Maine, New Hampshire, and Vermont. Florida and Delaware are also above the national average, but to a lesser extent.

Although the county statistics are not available on the number of dwellings held for occasional use, they are for the states as a whole. An unknown portion of these housing units are along the estuaries. It may be noted in Table 3 that, relative to the total population of the states, these houses are more characteristic of the southern states. It would appear that the second homes in New England tend to be held for use during the summer months but for year-round use in the South.

Nationally, this upsurge in the number of vacation homes indicates a trend that may be predicted to continue if economic conditions permit. The development of second homes will have a great impact upon the areas in which they are located.

Commuting

The vast majority of the population of the United States lives in the metropolitan areas of the nation. In these areas almost inevitably the home and work are separated. This journey to work is certainly a factor in daily existence of many people, but the phenomenon of commuting is much more complex than often is realized. For one thing, there are large numbers of households in which both the husband

and wife are employed outside the home. As a consequence, both are engaged in this journey to work. The pattern is not all that crucial at the present time in estuarine counties that are non-metropolitan, but indications are that it will become more important in the future.

Several studies have been made in recent years of the residential preferences in the United States. A Gallup poll in 1966 reported that 49 percent of respondents would rather live in a small town or rural area than a larger community. Two years later this figure had increased to 56 percent (Zuiches and Fuguitt, 1972: 622).

A survey in 1971 for the Commission on Population Growth and the American Future indicated that 64 percent of the U.S. population preferred to live in small towns and rural areas (1972:34). Investigations in Wisconsin add another dimension to these findings. Wisconsin residents also prefer to live in small towns and rural places, but most of these individuals want to be within commuting distance of major metropolitan centers (Zuiches and Fuguitt, 1972:626). Apparently, the person living within 30 miles of a large city can enjoy the quiet and tranquility of the countryside, but for the satisfaction of his needs, he is able to get to the large city in a short period of time. In other words, the individual residing within the commuting area of a major metropolis sees the opportunity for enjoying the advantages of both the rural and the urban environments.

The survey by Zuiches and Fuguitt also presented statistics that most people do prefer life in a residential area about the same size in which they were reared. This finding is especially true for those reared on the farm. As the size of a center in which a person was reared increases, however, a definite tendency is noted to be less satisfied with the urban areas and for people to express a desire for a more rural setting (1972:627).

Of course, a related question will be whether or not people move in terms of these preferences. A public opinion survey indicates that a relatively large percentage of the population believes that they will actually change their place of residence according to these preferences or that they reside in a desired location. Maize and Rawlings report that 80 percent of the respondents in a survey were either living in the preferred location or expected to eventually move to such a place (1972:608). Such a tendency is much more pronounced as the size of the center increases. Rather interestingly, whites are much more likely to move in terms of these aspirations than are blacks. In fact, urban blacks tend to be much more satisfied with their residential area than whites. Maize and Rawlings suggest that a reason for this is that many blacks were reared in rural areas where life was not kind to them and only in the cities have they found a more pleasant life than the rural setting of their childhood. A move back to the rural areas might be viewed as a step backward. (1972:607).

If these generalizations are valid for the southern coastal areas, they would explain why these areas have not been experiencing as rapid population growth as other coastal sections of the nation. Large numbers of southern blacks have moved to the cities of the nation, especially to northern ones during the past half century. This out migration has brought a sizeable decline in the population of some of the more rural coastal counties. In the near future, these counties will probably be able to experience rapid growth only through the immigration of whites who are searching a small rural milieu.

Certainly, the basic attitudinal dispositions exist that can bring a shift of residence toward the smaller towns and rural areas. Relatively few economic opportunities exist in sparsely settled areas. Thus, the incidence of commuting to work may be expected to grow.

One index of the extent of commuting is the proportion of workers whose place of employment is outside the county of residence. The Census of Population reports that in 1970, 17.8 percent of all workers traveled outside the county where they lived to work. This rate of commuting is lower in the western than the eastern states, no doubt in part because western counties tend to be larger. Nevertheless, it is significant that the highest commuting rates were in the states along the eastern seaboard. In Virginia, for example, 39.9 percent of all workers leave the county of residence to work. Next highest is Maryland with 36.7 percent, followed by New Jersey and New York with 32.7 and 31.8 respectively. Large metropolitan centers such as Washington, D.C., and New York City are the places of employment, but not of residence, of large numbers of people.

The data in Table 4 show that the percent of the population working outside the county of residence in the estuarine counties of the eastern seaboard was 50 percent in 1970, a substantial increase from the 37.8 percent in 1960. No tabulations were made on the extent of inward commuting, which is substantial in some areas.

Further, it may be noted that there has been a great increase in the number of people working outside the home county, from 29.7 in 1960 to 36.4 in 1970 (see Table 4). The general pattern has been for in-county employment to increase much less

Table 4.—Commuting in the estuarine counties of the Eastern Seaboard, 1960–1970

	Workers Residing in Area 1960		Workers Residing in Area 1970		Percent Change in Number of Workers 1960–1970	
	Number	Percent Working Outside County	Number	Percent Working Outside County	In-County	Out-of-County
Maine	144,321	11.8	164,286	13.7	11.5	31.6
New Hampshire	36,366	34.4	49,753	43.9	16.9	74.8
Massachusetts	954,803	23.8	1,051,978	29.5	2.0	36.6
Rhode Island	314,117	21.1	362,305	23.6	11.6	29.3
Connecticut	591,889	11.3	700,545	14.7	13.8	54.1
New York	4,360,154	39.3	4,461,025	44.5	6.4	15.7
New Jersey	1,838,624	30.0	2,129,583	34.7	8.0	34.1
Virginia	725,562	42.8	1,129,096	46.8	44.6	70.3
Maryland	833,353	31.6	1,588,326	59.1	14.1	256.1
Delaware	156,030	7.9	194,922	11.7	19.7	85.9
North Carolina	189,133	10.6	223,783	18.3	8.1	105.1
South Carolina	140,030	7.1	171,931	11.6	16.8	100.8
Georgia	93,243	3.7	95,531	5.6	0.5	53.1
Florida	802,332	5.0	1,150,296	6.6	40.9	90.8
TOTAL	11,179,957	29.7	13,473,360	36.4	12.8	47.7

rapidly than out-of-county employment. If present trends continue, commuting will involve a greater number of people than employment within the county of residence.

Women in Labor Force

One factor in the increase in commuting has been a trend for more and more women to enter the labor force. Large numbers of married women are now working outside the home. When both husband and wife are employed, it is unlikely that they will share the same journey to work. At times their hours differ, but more often, they go in different directions. If they are employed in locations miles apart, then one, if not both, must resort to commuting. The home cannot be near both places of employment.

Furthermore, if both husband and wife work, their income will be more adequate to maintain a suburban lifestyle. With increases in income, people tend to move out from the central city.

Patterns of life for a married couple change when both are employed. The increased participation of married women in work outside the home may be demonstrated by a few statistics. In 1950, only 23.8 percent of married women with husbands present were in the labor force. This figure reached 30.5 percent in 1960, but accelerated after that date to 40.8 percent in 1970 and 41.5 percent in 1972. The figures for the total adult female population show the same trend. In 1950, 31.4 percent of females above the age of 14 were in the labor force. This figure was reported as 43.6 percent in 1972.

Rates of participation in the labor force were not tabulated for the eastern seaboard counties. The same patterns are developing in this area as elsewhere. The total number of females in the labor force for these estuarine counties increased from 4,298,003 in 1960 to 5,546,198 in 1970, an increase of 29 percent. During the same 10-year period, the number of males in the labor force grew from 8,367,066 to 8,951,665, an increase of but 9 percent.

Undoubtedly, the employment of women outside the home is a major factor in the changing lifestyles of the coastal areas. Inasmuch as birth rates are declining, it may be anticipated that an increasing percentage of women would continue to look outside the home for fulfillment. This trend will, of course, be determined by the availability of employment.

Land Use Changes

Nationally, the number of acres in farms has steadily declined since the soil bank program of the 1950's. At the same time, the number of farms continued to decline from the peaks reached early in the century. Meanwhile, the average size of farms has increased. The family farm is giving way to the commercialized enterprise.

The number of farms in the estuarine counties of the eastern seaboard has dropped from 194,448 in 1950 to 72,049 in 1970, a decline of 62.9 percent in only 20 years. (Table 5).

The widely publicized world food crisis will probably result in the expansion of large scale agricultural enterprises along the eastern seaboard. Much of this area, especially along the South Atlantic coast, was at one time abandoned for agricultural purposes with the westward movement of settle-

Table 5.—Number of farms in estuarine counties on the Eastern Seaboard, 1950–1970

	1950	1960	1970	Percent Change		
				1950	1960	1970
Maine	12,075	6,778	2,664	−56.1	−39.0	−21.9
New Hampshire	2,206	1,076	427	−48.7	−39.7	−19.4
Massachusetts	7,899	3,947	2,132	−50.0	−54.0	−27.0
Rhode Island	2,598	1,395	700	−53.7	−50.1	−27.0
Connecticut	6,981	3,464	1,801	−49.6	−52.0	−25.8
New York	17,346	19,503	6,030	−12.4	−30.9	−35.0
New Jersey	17,274	10,790	5,481	−62.5	−50.8	−32.0
Virginia	36,134	19,781	12,255	−54.8	−62.0	−34.0
Maryland	21,426	14,746	10,229	−68.8	−69.4	−48.0
Delaware	7,448	5,208	3,710	−70.0	−71.2	−49.8
North Carolina	34,899	24,731	15,218	−70.8	−61.5	−43.6
South Carolina	18,900	11,645	6,072	−61.6	−52.1	−32.1
Georgia	2,301	1,158	582	−50.3	−50.3	−25.3
Florida	6,961	6,097	4,768	−87.6	−78.2	−68.5
TOTAL	194,448	130,319	72,049	−67.0	−55.3	−37.0

ment. Rice plantations in the lowlands of the Carolinas and Georgia were abandoned long ago. Timber companies presently own very large tracts of land. Other areas such as the Golden Isles off the coast of Georgia became hunting preserves and vacation retreats for wealthy citizens.

Under the demands for increased agricultural production, it is very probable that pressures will be exerted to convert present timberlands back to food production. Large capital investment requirements often result in large scale operations, sometimes referred to as "factories in the field." Indicative of this type of operation is the development by the McLean Corporation of most of Tyrrell County, N.C., into a tremendously large corporation farm of 375,000 acres. With heavy equipment, it is possible to convert this tremendously large acreage into huge agricultural enterprises over a very short period of time. Named First Colony Farms, this operation will have 225,000 acres under cultivation. Most of this land was in timber in 1972. Now it is becoming a factory that will produce corn and soybeans to be fed to cattle and 50,000 hogs.

The concentration of land ownership simplifies the creation of this kind of enterprise. The plea that people throughout the world are starving to death and that the citizens of the United States are threatened with imminent starvation makes it extremely difficult to halt or control these developments. Low agricultural yield in 1974 for the Midwest has been interpreted as a harbinger of worldwide shortages in the future. Continued pressure to open new areas of the United States to agricultural production is a likely consequence.

The Southern Atlantic States provide one of the best opportunities for large corporations to develop factories in the field in the shortest possible time. The availability of water and the natural fertility of soil that has remained fallow for many years provide the potential for tremendous agricultural yields.

Obviously, the draining of swamps and the destruction of ground cover would drastically alter the ecology of the area within a short time. The impact of the runoff on the estuaries would be quite dramatic.

Only part of the land taken out of agriculture has been converted to highways, urban residential areas, industrial development, and the like. Such diverse uses receive much attention in the press. But a significant portion of the lands that were in cropland are not used for forestry and grazing. Forest lands in the United States have increased substantially over recent decades. No tabulations were made of the acreage in the estuarine counties that has returned to forests during recent years. Woodland not in farms increased from 127,358 thousand acres in 1959 to 146,733 thousand acres in 1969 for the states along the eastern seaboard. Of these coastal states, only Florida failed to register an increase in its forested area during the period.

At the other extreme, there are developments which significantly change the use of the land. New highways, shopping centers, and the like are known to all. However, one change has been largely ignored, and accurate statistics of the phenomenon do not exist. The average residential lot has steadily increased in size with suburban growth. The single family urban dwelling of two generations ago occupied a relatively small space. Lot size was adapted to the pedestrian. Today, a new single family dwelling in the suburbs requires a much larger space. One reason for this change is that zoning regulations often specify that the new residential lot be much larger than was true in the past (Gottman and Harper, 1967:87).

Along the eastern seaboard the future will probably bring an increase in the amount of land under cultivation, a decline in the forested area, and an increase in the urban type usages of the land that result in great ecological changes. Such changes will undoubtedly have a significant impact on the water in the estuaries.

New Living Arrangements

The number of dwelling units in the United States has been increasing much more rapidly than the population. The number of residential units in the counties of the eastern seaboard, for example, grew from 6,193,753 in 1950 to 12,078,450 in 1970, an increase of 98.8 percent. The residential unit tends to be a more important entity than the individual in terms of utilization of resources. Each house requires plumbing, roads, utilities, lot space, and a variety of services. Obviously, there has been a decline in the average number of people per dwelling unit. Several factors are involved in this change:

1. During the depression years and earlier, families tended to often share the same residence. Married children were, especially, inclined to live with parents until financial security was reached. Full employment and prosperity have permitted most couples to have separate dwellings.
2. Another important factor is the increase in one-person households. In the past, the individual living alone was generally an elderly widow. A shift has taken place in recent years. Young employed adults, both male and female, seek a separate dwelling unit until marriage. Even among the college students, there has been a rapid transition to the apartment and away from the dormitory. The demand is for housing for individuals, not families.
3. Much residential construction during the last decade has been of apartment complexes. These units cater to the individual desiring to establish a one-person household. In 1960, 237,000 structures were built with three or more housing units. By 1970, this figure had increased to 606,000. Only two years later in 1972, 646,000 housing structures with three units or more were started. Apartment construction has multiplied rapidly, but each unit tends to have a small number of occupants on the average. Some apartment-style construction has been outside the cities in former open country areas, and has created environmental problems.
4. Yet another dramatic change in living arrangements has been the growing popularity of the mobile home. The shipment of mobile homes increased from 216,000 in 1965 to 576,000 in 1972. The mobile home has become especially popular in rural areas of the South. Financing has been easy to secure for those owning land. Few consider them as a permanent solution to housing needs. However, in a short time a person can have one installed and move into it, often without satisfactory provision for disposing of household effluent. Many mobile home parks have been established along the estuaries of the southern United States with raw sewage draining directly into the streams.

In addition to the mobile homes that serve as a regular residence, there are smaller units used by vacationers to camp in great numbers in trailer parks throughout the nation.

THE QUEST FOR QUALITY OF LIFE

For the last four or five years, everyone seems to have been seeking some elusive goal now designated as quality of life. The phrase was not a part of the vernacular a very few years ago. Now suddenly it is very widely used. Many scholars are now writing on the topic. Most of these essays are non-scientific and describe the kind of situation that the individual feels is ideal without any attempt to really specify the content of the quality of life. At one time, quality of life represented the goal of attaining trappings of affluence: automobiles, refrigerators, television sets, and other material things.

There is considerable evidence today that people are no longer as oriented toward material things. New lifestyles are evolving, that is, the manner in which material things are utilized. For example, an automobile may be used simply as a means of transportation to and from work, or it can be a source of livelihood, a status symbol, or even a major item of recreation. Today in our affluent society all tend to possess a vast array of material goods. The non-material life patterns, consequently, are becoming increasingly important.

The quality of life that is being sought has great ramifications for water pollution. The desire to visit the wide-open spaces, to go fishing, backpacking, camping, and the like are bringing great numbers of people into the areas that were uninhabited just a few years ago. As a consequence, there is really very little land in the United States that is not used for some purposes, whereas in the past, even around urban concentrations, there were still large tracts of lands that no one visited.

Indicative of the attempt to find a new style of life is the number of people who fish and hunt. The total number of fishing licenses issued nationally in 1950 was 15,338,000. By 1971, this figure had increased to 32,384,000. The number of hunting licenses sold jumped from 12,638,000 to 22,912,000 during the same 11-year period.

The number of outboard motors in use increased from 2,811,000 in 1950 to 7,400,000 in 1972. Outdoor recreation is a part of the desired quality of life of growing percentages of the population. It is a part of the general desire to live closer to nature.

Not to be ignored in this process of seeking a new quality of life are the amenities provided exclusively by urban living in the past. Early in the present century, only in the city could a person find modern bathrooms, running water in the kitchen, and electricity which made it possible to have refrigerators, electric lights, radios, and many of the other conveniences of life. These were undoubtedly one of the features of urban life that brought many to the city who could have stayed in the rural areas practicing a subsistence agriculture or living during the retirement years. Through the spread of electricity into even the remote sections of the United States, the rural resident can have all of these advantages of urban life. As a consequence, migration to a rural area does not involve a loss of these modern conveniences. In the affluent society, they provide a base of material comfort that is universally available in the United States. Increase in the quality of life is almost always followed by an even greater increase in the use of water and volume of waste materials.

Other amenities in the new style of living are coming into existence. One of the most important of these is climate. Ullman noted almost a generation ago that "for the first time in the world's history, pleasant living conditions—amenities—instead of more narrowly defined economic advantages are becoming the sparks that generate significant population increase, particularly in the United States" (1954:119). Ullman insists that the suburban movement reflects this search for a more pleasant life. Between 1940 and 1950, the suburban population of the nation increased 35 percent as compared with 13 percent inside the city limits and only 6 percent elsewhere. At the same time, other areas, largely coastal, with pleasant climate experienced a tremendous upsurge in their population. In the decade of the 40's the population of California increased 53 percent, Arizona 50 percent, and Florida 46 percent. Two other coastal states that also experienced this rather rapid rate of growth were Oregon and Washington, whose populations increased 39 and 37 percent respectively. Ullman considered climate a major factor and believed that most people would prefer to live in an area where the temperature averaged 70 degrees the year round. This "Mediterranean" type climate exists in Florida and California.

Even industry that is freed by modern transportation and communications from the inner city has viewed the climate as a major element in building new industrial establishments. Climate shows no signs of declining in importance. We may anticipate a continued movement of the population toward the coastal areas. The only large, undeveloped coastal area remaining in the United States is that of the southeast states.

CONCLUSIONS AND RECOMMENDATIONS

In contrast to the situation in western portions of the United States, the eastern seaboard has a relatively ample supply of water. Evidence is accumulating that water will be the natural resource that limits human development more than any other throughout the world. Adequate water supply does not mean there will be no problems in regards to this valuable resource. Just as important in many ways as the quantity of water available is its quality.

Industrialization, urbanization, and rapid growth of the population have often been associated with increased water pollution. The theme of this report has been that the changing life patterns of mankind have more influence upon the quality of the water in the estuaries than the mere numbers of people.

Several trends have been enumerated which reflect changing lifestyles in the United States and which must inevitably have some impact upon the estuaries:

1. The population of the United States is rapidly shifting to the coastal areas of the nation, while other sections are being depopulated; especially are people leaving the interior sections of the nation. Approximately one-half of the over 3,000 counties in the United States lose population each decade. At the same time, a new urban structure is evolving. The megalopolis of the northeast, extending from Massachusetts to Virginia, represents an attempt by man to combine elements of rural and urban living. Another megalopolis has been established along the east coast of Florida that promises to eventually encompass the entire peninsula of Florida. Population growth has been slower in the coastal areas of the south Atlantic coast. Indications are that a megalopolis is developing that will extend along the entire eastern seaboard. In the absence of careful planning, the water pollution problems of the northern coastal area may be expected to be duplicated in the South.

2. The trends toward a shorter workweek, paid vacations, late entry, and early exit from the labor force result in people today having much more time for leisure pursuits than was true for past generations. Much of this additional time is devoted to outdoor recreation, travel, and a demand for services on the part of the entire spectrum of social groups in the United States rather than a small leisure class.

3. A third trend in modern society has been the withdrawal of people from the labor force upon retirement in the 60's. Increased life expectancy has resulted in a much larger percentage of the population achieving advanced ages and enjoying several years outside the labor force. These retirees increasingly have a stable income from social security and various pension plans. Large numbers of retirees

are moving from the location where they spent their economically productive years to complete their lives in the coastal areas of the nation, especially those sections where the climate is mild.

4. Before the advent of automotive transportation, workers lived at a location where the journey to work could be minimized. Today, an ever-increasing percentage of the population is commuting daily from homes in the suburbs to employment a considerable distance away. As the journey to work becomes ever greater, dependence on public transportation has declined, and the automobile has become the focus of new lifestyles.

5. The small family pattern, modern household appliances, plus smaller homes have eliminated much of the drudgery of housework. Women, as a consequence, have increasingly sought employment outside the home. Their additional incomes make it possible for families to enjoy a higher level of living than before, which is often manifest in establishing residences away from the central city. Because husband and wife work in different locations, commuting must become a part of their lifestyles.

6. Land use has dramatically shifted along the eastern seaboard over the last 100 years. The number of farms has declined rapidly for decades. Initially, this decline resulted in lands being abandoned for agricultural purposes and becoming reforested. The growth of cities and the construction of highways and other facilities will probably bring a decline in forest acreage. Pressures to produce food for a hungry world may result in much land in the South Atlantic area being converted to large "factories in the field." Huge corporation farms would drastically alter the ecology of an area. Demands also exist to transform lands into public recreational facilities or to retain them as unchanged natural areas.

7. One of the most striking trends in the United States has been the increase in number of dwelling units. One-person households and the disappearance of the doubling-up of families have resulted in a steady decline in the number of people per residential unit. The housing unit tends to be the entity that disrupts the ecology of an area, rather than the number of people per se.

8. A dominant theme in American society today is the quest for a new quality of life. The term has not been adequately defined, but there is an unmistakable desire on the part of many people to follow some of the life patterns that existed when life was much simpler in the rural areas. These new lifestyles are associated with a desire for more contact with nature, not only as a place of residence, but also as a place to spend leisure time.

One of the reports for the Commission on Population Growth and the American Future summarized the trends in the redistribution of the population as follows:

> 1. People are vacating extensive portions of the nation's territory—particularly the middle of the continent—and concentrating along the coasts.
> 2. The United States becomes more and more urban with each passing year; most Americans now reside in metropolitan centers of at least 100,000 inhabitants.
> 3. The structure of these urban settlements is undergoing a gradual metamorphosis; metropolitan areas and their hinterlands are merging into larger constellations to form urban regions.
> 4. Important internal differentiations are taking place within the jurisdictions of metropolises; inside, their population is leveling off or shrinking and changing to nonwhite; in the suburban rings, it is expanding and remaining largely white.
> These changes have given rise to national problems concerning the environment, the aesthetic quality of urban and rural life, and racial separation—issues of coping individually and collectively with the process of urbanization. Curtailing national population growth, while helpful in the long run, cannot resolve these problems in the near term (Morrison, 1972:23–24).

The Commission on Population Growth and the American Future strongly recommended that the policies of this nation be built about the concept of population stability rather than growth. The Commission insisted in the long run there must be a population stability because even an infinitesimal rate of population growth cannot continue indefinitely (1972:75–79). It is recognized that population growth may very well continue for some decades, but the Commission insisted that thinking and planning must be based on population stability.

Many people find it difficult to adjust to this concept of stability. Our economy has been based on some inflation as well as population and city growth. Bigger has long been considered better. Rapid population growth accompanied with inflation and industrial expansion has been sufficient to compensate for poor planning. Population stability will result in new homes which are needed only for replacement of those being abandoned. Inflation which assures a profit on manufactured products cannot be continued indefinitely. The pessimistic volume, "The Limits to Growth," written by a group of experts from Massachusetts Institute of Technology (Meadows, et al., 1972) projects global collapse coming as a result of population growth. If equilibrium is not reached in population growth, perhaps through increased pollution, industralization, urbanization, and the destruction of nonrenewable resources, the calamity these authors forecast would come about.

Still, not all present trends will continue. One way to assure a reversal in the direction of change will be the adoption of policies that enforce population stability plus restrict other forms of development. A situation of population equilibrium will almost undoubtedly result in more careful planning of the location of schools, highways, residential areas, industrial plants, and even agricultural operations.

This planning almost certainly will result in more consideration being given to the natural environment, especially in those areas where unhampered development can lead to greater water pollution.

With this background, three recommendations of the Commission of Population Growth need to be adopted if the estuaries of the nation are to be protected:

> 1. Recognizing that our population cannot grow indefinitely, and appreciating the advantages of moving toward the stabilization of population, the Commission recommends that the nation welcome and plan for a stabilized population (1972:143).
> 2. The Commission recommends that: The federal government develop a set of national population distribution guidelines to serve as a framework for regional, state, and local plans and development;
> Regional, state, and metropolitan-wide governmental authorities take the initiative, in cooperation with local governments, to conduct needed comprehensive planning and action programs to achieve a higher quality of urban development;
> The process of population movement be eased and guided in order to improve access or opportunities now restricted by physical remoteness, immobility, and inadequate skills, information and experience;
> Action be taken to increase freedom in choice of residential location through the elimination of current patterns of racial and economic segregation and their attendant injustices (1972:144).
> 3. To anticipate and guide future urban growth, the Commission recommends comprehensive land-use and public-facility planning on an overall metropolitan and regional scale.
> The Commission recommends that governments exercise greater control over land-use planning and development (1972:144).

Although relevant to the process of water pollution in the estuaries of the eastern seaboard, these recommendations of the population commission are general and apply to the nation as a whole. There are other recommendations that need to be made which are more unique to problems existing in counties along the estuaries of the Atlantic coast. These specific recommendations are as follows:

1. That new legal entities be created whose jurisdiction will be independent of existing political subdivisions. Problems of planning code enforcement must encompass the whole region rather than discreet, competing parts thereof.

2. That intensive demographic and sociological studies be undertaken that will equate changing lifestyles with the new emerging urban structure, the eastern seaboard megalopolis.

3. That these studies by social scientists be integrated with interdisciplinary studies in cooperation with natural scientists in order to better understand the ecological problems of the eastern seaboard.

4. That regional zoning be accomplished which will restrict the use of the land for recommended purposes. Such a zoning plan must necessarily ignore existing political boundaries.

5. That growth along the eastern seaboard be controlled through the construction of a transit system the entire length of the Atlantic seaboard in accordance with plans for the ideal utilization of various zones. Land use and development is a function of the system of transportation.

6. That special studies be made of the South Atlantic coastal area and contrasted with developments along the North Atlantic coast. Such studies are essential if problems that had been generated in the Northeast are not to be duplicated in the South.

7. That regional plans be made for the provision of utilities and, especially, public health facilities for the entire coastal area. Regional building and sanitary codes are needed that cannot be ignored by smaller political divisions.

8. As this is being written, problems of energy, inflation, and unemployment add to the urgency for planning. However, these plans must be based on a sound understanding of the relationship of the immediate situation to both past and long range future developments.

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ESTUARINE ECONOMICS

ECONOMIC ANALYSIS IN THE EVALUATION AND MANAGEMENT OF ESTUARIES

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ABSTRACT

This paper describes an economic-environmental systems model for analyzing estuaries which has been used in Maryland to forecast the quantities and types of waste and residuals which will be generated through the year 1985 for the Chesapeake Bay and each of its major tributaries. The model indicates that the amount of residuals will be a function of the rate and composition of economic development. Consequently, economic development and growth in the region can be expected to generate water quality problems of increasing magnitude for all estuaries in the U.S. Various corrective policy measures are evaluated for dealing with the environmental threat to the quality of estuarine waters. One of the most serious environmental impacts is aesthetic damage and methods are suggested for applying charges for various levels of aesthetic damage in order to encourage improved qualities of economic development.

A national policy on estuarine management would recognize both the economic realities of common property resources and the federal structure which has evolved in U.S. political history. Consequently, a national policy on estuarine management would establish minimum national standards for quality, leaving local authorities to establish higher standards if so desired. However, no economic or political justification can be discovered for permitting local areas to relax environmental standards below those set by federal government. The establishment of higher local standards than those stipulated by federal policy would provide financial and other incentives to improve technology and encourage generators of pollution to internalize external costs. Finally, specific recommendations are made for establishing a national policy for better management of estuaries, which are among our most important natural and environmental resources.

INTRODUCTION

Estuaries are the vital interface between land and water, between oceans and rivers, between ecology and technology, and between the conflicting demands for environmental quality and economic development. Estuaries are the bodies of water over which will be fought the emerging battles for energy production versus conservation and economic growth versus the reduced growth movement. The problem of analyzing and resolving these conflicts will require a more complete understanding of the relationships between man and his environment and the relationships between the social, physical, biological, and earth sciences than has been available in the past.

The accumulation of economic and other reinforcing institutional factors which encourage overuse and mismanagement of estuaries is a growing threat to water quality and biological, ecological balance in the nation's waterways. Environmental economists are attempting to measure, forecast, and analyze these phenomena by developing new types of models based upon tested economic tools combined with materials balance and entropy concepts derived from the physical sciences. Some of these large-scale computer models are now capable of estimating the generation of many individual wastes, residuals, and pollutants over time throughout different parts of the estuary. For example, Table 1, taken from one such study, estimates the gross generation of residual nitrogen generated in each of the 16 major river basins of the Chesapeake Bay by 5-year intervals from 1970 through 1985 (Cumberland and Herzog, forthcoming). This study estimates an average annual growth rate for nitrogen releases of 5.7 percent, but with significant variance between the individual political subdivisions and river basins involved. This annual growth rate, if continued, implies a doubling of the pollution load approximately every 14 years.[1] These projected pollution growth rates underline the urgent need to develop more effective control measures if society is to enjoy benefits of these resources in future generations.

[1] Similar estimates are available in the study for growth of other pollutants, as well as for the accompanying economic development in each of the major river basins which make up the Chesapeake Bay Regional System.

It is the major point of this paper that current mismanagement of our estuaries results from omissions and inadequacies in the conceptual models and management theories which have been applied to the governance (or more generally, the non-governance) of estuaries. Among the more serious gaps in our models for managing estuaries are: failure to include the lessons of environmental economics; failure to include new interdisciplinary knowledge and concepts such as materials balance and energy-entropy models; failure to use models based upon a total systems approach; and failure to use models which reveal comprehensive sets of alternative management policies and their consequences. This paper will attempt to address these problems by sketching a comprehensive systems analysis which can be applied to estuaries, by indicating some of the implications of the systems approach, and by examining briefly some of the management policies and possible improvements in management techniques which are suggested by the analysis.

Table 1.—Gross Residual Projection for Nitrogen for the Chesapeake Bay Region (tons)

	Years				Average Annual Growth Rate 1970–1985
	1970	1975	1980	1985	
District of Columbia					
Potomac	4,032.7	4,252.4	4,746.8	5,214.8	1.7
Maryland					
Blackwater	487.2	525.0	542.5	551.6	.8
Chester	4,696.4	5,526.3	6,336.1	6,876.6	2.6
Choptank	10,721.2	11,868.7	12,816.9	13,440.2	1.5
Gunpowder	4,462.4	5,029.4	5,400.6	5,560.9	1.5
Nanticoke	3,088.9	3,340.6	3,495.8	3,617.2	1.1
Patapsco	6,309.8	6,309.8	7,139.6	7,212.5	.9
Patuxent	12,641.5	13,802.7	14,078.7	14,421.6	.9
Pocomoke	6,802.5	7,291.6	7,521.9	7,772.2	.9
Potomac	47,979.5	50,891.9	52,343.6	52,482.8	.6
Wicomico	8,067.9	8,624.9	8,875.6	9,145.6	.8
Elk	3,898.1	4,460.8	5,069.7	5,575.7	2.4
Ches. Bay and ocean	30,092.2	32,602.6	34,425.1	35,634.6	1.1
Total	139,247.4	150,504.0	158,045.9	162,291.4	1.0
Virginia					
James	29,956.5	48,850.0	79,234.1	122,084.0	9.8
Potomac	15,088.8	23,024.4	35,782.5	53,028.2	8.7
Rappahannock	12,799.8	22,386.9	38,444.0	62,038.6	11.1
York	10,840.1	17,875.6	29,481.1	46,196.8	10.1
Ches. Bay and ocean	12,592.4	16,292.5	21,398.4	27,888.4	5.4
Total	81,277.6	128,429.4	204,340.0	311,235.8	9.4
Chesapeake Bay Region total	224,557.7	283,185.8	367,132.7	478,742.0	5.7

Source: Cumberland and Herzog, forthcoming.

SOME SOURCES OF ENVIRONMENTAL DAMAGE TO ESTUARIES

The major threat facing our estuaries is cumulative and potentially irreversible environmental damage resulting from excessively rapid economic development and intervention in natural processes. Although numerous factors have contributed to this problem, a major set of components has emerged from economic forces.

The principal economic problem in the management of estuaries is the fact that they are generally treated as common property resources with no single ownership or management. Consequently, property rights are not vested and the result is that estuaries and their resources tend to be overused and abused since users do not normally bear the full costs of their use. Under these circumstances, market failures result since the private costs of using the resources of the estuary do not equal the social costs and the individual users attempt to appropriate as much of the resources as possible before they can be appropriated by others who also have free rights to them. With no single entity holding property rights or full management responsibilities, there are no incentives to invest in increasing or protecting the productivity of the estuary, and its resources tend to be overused and depleted.

Another problem which is related to the common property phenomenon in estuarine management is the imposition of detrimental externalities on others. The apparently free availability of water, air, and biological resources in estuaries makes it possible and profitable (at least in the short run) to overuse these resources and to shift costs from particular individuals, groups, and communities, to others. This phenomenon is most clearly observed in the release of wastes into the air and water of estuaries. Firms attempting to maximize profits, individuals attempting to maximize personal utility, and communities attempting to minimize costs and shift their environmental loads elsewhere, face positive incentives to discharge their wastes into estuaries, thus imposing damages, costs, and injuries upon other groups, other reaches of the estuary, and upon the biological resources of the estuary itself without paying compensation.

Other types of market failure also combine to encourage mismanagement of estuaries. For example, many of the recreational, aesthetic, and environmental values of estuaries can be regarded as public goods which are normally provided in the public sector. Although the benefits resulting from the provision of these public goods usually exceed their costs, up to a certain level, the public sector normally provides insufficient investment in the management and protection of estuarine services, for a number of reasons. Taxpayers may be reluctant to reveal their preference for added expenditures in the public sector fearing that their taxes will be raised and hoping that other groups and other regions will pay for the improved management. The joint difficulty of either collecting fees for cleaner waters or of excluding anyone from enjoying the free benefits therefrom is a serious deterrent to public programs needed to protect estuarine quality. Also, organized pressure groups with well-defined financial objectives are usually more successful in influencing public expenditures in their direction than is the general public which benefits from the diffuse, long-term services of a well-managed estuary.

Another problem in the management of estuaries is the failure to utilize models which permit experimentation with a wide range of alternative development plans. Too often in the past, preoccupation with growth and quantitative increase of gross product has tended to distract attention from other alternatives such as non-development, low-density development, recreational development, and protection of common property resources for the future. Flexible models are needed which can trace the economic and environmental implications of all of these policy alternatives.

Two major sets of problems in estuarine management are caused by the inability of current economic management models to allow full consideration of interregional, interspatial, and intertemporal phenomena. With respect to intertemporal phenomena, decisionmaking for estuaries is typically based upon market rates of discount and profit considerations which attach low values to the rights of future generations. The result is often to encourage irreversible actions which may generate current benefits at the cost of foreclosing future alternatives. More adequate consideration of the values of future generations is required.

The failure to consider future generations and the use of high discount rates also tend to ignore important time changes in economic variables. For example, there appears to be growing evidence that with affluence, there is a high income elasticity of demand for outdoor recreation; yet, adequate protection of estuaries for recreational purposes has been systematically undervalued as compared to industrial and commercial development. A second and related phenomenon results from changing technology. For example, the rush to use the cooling capacity of estuaries for installing fossil fuel and nuclear electric steam power stations overlooks probable future technological developments which will make more use of solar, geothermal, and other forms of energy less damaging to the environment than present steam electric stations (Krutilla and Cicchetti, 1972). Another phenomenon connected with technology is the growing tendency towards introduction of high-technology, high-pollution devices in recreation. For example, the growing use of high-powered engines for water skiing, boating, helicopters, and other aircraft is converting many recreational activities into high-noise, high-pollution activities.

Other problems related to time in the theoretical analysis of estuarine management deal with the neglect in most resource management theories of the irreversible nature of some activities. For example, some types of estuarine abuse such as excessive sedimentation and filling in of the estuary, or massive oil spills, or the releases of radioactive isotopes with very long half-lives may have an effect on the estuary that is irreversible. Reversibility can be defined in terms of the amount of cost involved in correcting an adverse effect. Under this definition, certain types of management decisions may be irversible, or they may be reversible only at extremely high costs. Among these would be the decision to construct a highly capital intensive activity such as an industrial plant, a power plant, an industrial port, or even a high density recreational or residential area. The phenomenon of irreversibility as it affects estuaries therefore requires that sequential life-cycle analysis be included in models of estuarine management under which the economic and environmental effects of the project should be evaluated over all phases of its life. This would include exploration, planning, construction, operation, and the eventual removal of the project and rehabilitation of the site.[2] The inclusion of intertemporal, sequential phenomena is urgently needed if models of environmental estuarine management are to be improved (Fisher, Krutilla, and Cicchetti, 1972; Fisher and Krutilla, 1974; Arrow and Fisher, 1974).

Besides including intertemporal phenomena, improved models should explicitly contain interregional, interspatial variables. A major tendency in regional waste management problems is to shift emissions of wastes to other regions, using common property resources such as air or water to transport waste burdens from one region to another. Much traditional analysis of urban problems fails to take into account the total environmental space of an urban region, which properly includes its entire watershed and its entire waste disposal space, covering perhaps hundreds or thousands of square miles. Consequently, estuarine models should explicitly contain the full environmental space of the region as well as an

[2] The closer the costs of removal and rehabilitation approach infinity, the more nearly the project would be truly irreversible.

explicit interspatial network of all of the separate governments involved.

Closely linked to the regional economic factor is the regional political management problem and the need for appropriate management units for estuaries which include the relevant physical and environmental units. Related to this is the fact that responsibility for estuarine environmental decisionmaking is often entrusted to transient personnel who may have at best a short-term or bureaucratic interest only, rather than a long-term commitment to the health and protection of the estuary. Another institutional management problem is the failure of environmental planning units to include representatives of all of the necessary disciplines involved. Too often these regulatory commissions have a commitment to economic development rather than environmental protection. Political factors obviously reinforce this issue.

The net result of all of these economic and related problems in estuarine management is usually to encourage excessively rapid development, overuse, and abuse of common property environmental resources so that private costs are lower than the social costs. The private gains resulting from damage to the public interest offer incentives to individual developers to overuse the resources of the estuary. The resource management problem then turns out to be in large part one of avoiding the major abuses of market failure through simulation of optimal decisionmaking which in theory results from single management and ownership of an environmental resource.[3] The estuarine management task then is to maximize public welfare and utility by balancing the gains of economic development against the claims of responsible environmental management in order to maximize total net social benefits to the society. It is the hypothesis of this paper that failures to do this in the past have resulted from 1) inadequate theoretical understanding of estuaries; 2) failure to include interdisciplinary knowledge that is emerging from ecological analysis of estuaries; 3) failure to base estuarine management models on knowledge of environmental economics; 4) failure to design models which show all of the full range management options; 5) failure to include long-run phenomena; 6) and failure to design adequate institutions which can implement the knowledge resulting from better management models.

In the next section, an effort will be made to sketch some of the details of a comprehensive estuarine environmental systems management model.

[3] Optimal decisionmaking also requires the free availability of knowledge, low transactions costs, and other conditions usually associated with pure competition.

APPLICATION OF SYSTEMS ANALYSIS TO ESTUARIES

Estuaries are complex systems of natural phenomena, of human activities and of the interrelationships between society and nature. The realities of these large systems are too complex to be represented by simple models. However, as in the case of any management problem, an effort can be made to identify the most critical subcomponents of the estuarine system and the interrelationships between them. Figure 1 represents an effort to model the major components of an estuarine system and its interrelationships.[4] It contains eight components which, being separate and distinct, can be solved individually, but which can also be linked together with measurable interrelationships in a way which provides feedback from one system to another, generating a closed general equilibrium system. Part A is a regional, or more generally an interregional interindustry or input-output model which has been widely used by economists (Cumberland, 1966). There are several important characteristics of these interindustry models. One distinctive feature is the emphasis on disaggregation of economic systems by type of economic activities. For example, Figure 1 specifically identifies energy sales across the energy row and energy purchases down the energy column, because of the importance of energy policy problems at the present time and because of their significance for estuarine management. However, because energy activities purchase inputs from many different activities as shown in the energy column and because energy producers sell outputs to almost all other economic activities, as demonstrated across the energy row, it is impossible to measure and evaluate energy activities in isolation from the rest of the economy. Therefore, separate analysis of energy isolated from the rest of the economy can lead to erroneous, misleading, and inefficient decision processes. Energy factors should be incorporated explicitly in a general equilibrium model of the region.

A second major advantage of the interindustry module is that separate identification of each economic activity in the model permits the comprehensive measurement of indirect, as well as direct, effects of each of the economic activities. This is important because indirect effects if comprehensively accounted for can add up to significant magnitudes. Another advantage of the disaggregation of the interindustry

[4] Although the economic environmental systems model displayed in Figure 1 is used for application in this study to estuaries, it has been developed by the author and his colleagues for general application to economic environmental management problems of regions, urban areas, and other systems. See for example (Cumberland and Stram, 1974; Cumberland and Korbach, 1973).

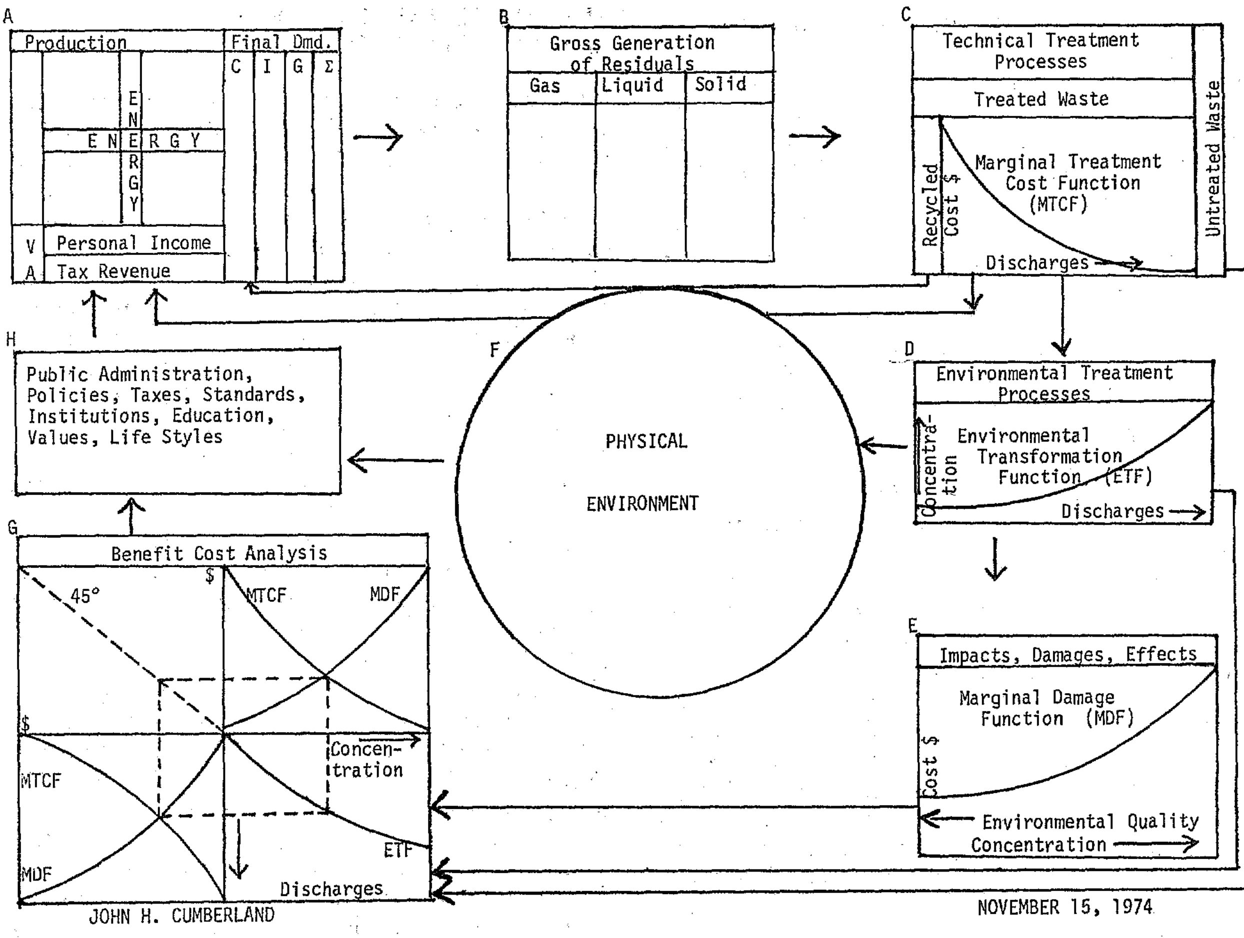

FIGURE 1.—An economic environmental systems model.

model by economic activity according to function is that it records the important distinction between the final demand sectors and intermediate processing sectors. This distinction permits recognition of the fact that economic growth is not mechanical or inevitable, but is a function of the goals and priorities of the region. The decisionmaking sectors are separately identified as consumers or investors or government for whose total final demand satisfaction the intermediate processing sectors are activated. This formulation has the important additional advantage of making it possible to enter alternative growth strategies or policy programs into the model (so long as they can be specified in terms of purchases from the sectors in the model) in order to measure the impact of these alternatives on income, employment, output, and environmental quality. In an alternative linear programming formulation, the model can also be used for indicating, given the goals and objectives of the estuarine region and its environmental structure, the optimal set of economic policies and activities needed to achieve these regional objectives. Trade-offs between environmental quality and economic objectives such as income, employment, and tax revenue can also be measured.

While economists have achieved considerable proficiency in developing the economic models of the type shown in Part A, they have learned recently from the growing magnitude of environmental problems that economic models have omitted some of the most important interrelationships from their market-oriented models. Since interindustry models normally measure only those goods priced and exchanged in markets, they have omitted the flows of wastes and residuals which are a counterpart of all production and consumption activities. Although the materials and energy balance concepts have been dealt with by physicists for many years, they have only recently been introduced into the analysis of economists (Ayres and Kneese, 1969; Georgescu-Roegen, 1971). Profit-maximizing firms have economic incentives for discharging their wastes at low or zero costs into the common property resources of the estuary, causing overuse of the limited assimilative capacity of estuaries and reductions in total welfare. The abuse of the common property estuarine resources is not limited to profit-maximizing firms, but is also a factor in the economic incentives of consumers and recreationists to discharge their wastes into estuarine waters, and to overuse the common property amenities provided by estuaries.

Thus, difficulties associated with allocating and enforcing property rights to estuarine resources, and the historical common property status of the estuary which provides positive financial incentives to both producers and consumers to overuse these resources and discharge wastes into them, account largely for the environmental problem and the growing pollution of estuaries. An attempt is now being made to measure the flow of these wastes and residuals through the environment in new types of development models which measure and forecast both the types and the amounts of wastes that accompany each type of production and consumption activity (Cumberland and Korbach, 1973). This type of model measures the flow of wastes and residuals coming from each type of economic activity in the Gross Residuals Component B of Figure 1. The model is disaggregated not only with respect to every production and consumption activity, but with respect to each major type of pollutant discharged into water, air, and onto the land. The importance of disaggregating waste by type, source and destination can be suggested by considering the different environmental qualities and characteristics of different estuaries. Estuaries having cold water and great depths, such as Puget Sound, may be less damaged by some types of residuals (i.e., thermal) than would other estuaries, such as the Chesapeake Bay, which is characterized by shallow depth and warm waters. This type of model measuring the gross generation of residuals is a logical extension of economic interindustry models and now is being implemented by numerous research groups.

The growing importance and necessity of treating wastes and residuals makes it important to develop models of the alternative procedures and the costs involved in treating wastes and making them less harmful. This type of information is included in The Technical Waste Treatment Component, C, of the systems model, which includes the many technological options for treating each type of waste in each location. A critical point to be noted about technological treatment of wastes is that while residuals can be treated in many ways—through dilution, transportation, recycling, changing the timing and place of the emissions, improving efficiency, choosing cleaner inputs, and so on—these treatment processes cannot eliminate or reduce residuals once they have been generated, because of the principles of conservation of mass and energy. Most treatment processes can only change the form or timing or location of the wastes discharged, and indeed add to the total mass of wastes released because of the necessity of adding energy and materials to the treatment process. The general exceptions to this principle are processes which use cleaner inputs, and processes which through technological efficiency use less materials and energy for the production process.

The other important factor to be noted about Component C dealing with technical waste treatment processes is the nature of marginal treatment cost functions which should be conceived of as being derived for each type of residual at each location over time. In general, these treatment cost functions rise asymptotically from the lower right-hand part of the diagram to the upper left-hand part of the diagram as increasing levels of treatment are invoked in order to achieve higher levels of treatment. The general shape and location of this curve suggests that large amounts of waste can be treated inexpensively[5], but that as higher levels of treatment are attempted, efforts to extract the last few percentage points of the residual and to achieve further increments of environmental quality, raise the costs of treatment per unit sharply.

The materials balance concept behind Component C for Technical Waste Treatment Processes is based upon the principal that wastes and residuals once created, cannot entirely be eliminated, and that the amount of residuals generated is a function of the level of economic activity, even if treatment processes are widely employed. Society is already encountering the problem of wastes which come out of waste treatment processes. Problems of dealing with the sludge from advanced waste treatment processes, and problems of the potential emissions from automobile pollution control devices are examples. The growing evidence of heavy metals and viruses to be found in residuals from sewage treatment processes provides another potentially significant example of this problem. Thus, the problem of contamination of the output of waste treatment processes by wastes from other processes may impair the capability of society for recycling wastes back into the economic system.

As shown in the Environmental Treatment Process

[5] For some treatment processes, economies of scale may cause high initial treatment costs, which then decline before ultimately rising. More empirical investigation of this problem is required (Grigalunas, 1972).

Component, D, of Figure 1, one of the major reasons for mismanagement and overuse of estuaries is the limit to the absorptive capacity and waste treatment capability provided by natural systems in estuaries. This phenomenon accounts in part for the powerfully attractive force which estuaries exert upon the location of industrial development, urban growth, power plants, and industrial harbor complexes. Water and other environmental resources of estuaries can receive, transport, transform, and treat large amounts of wastes which are discharged from natural processes and indeed from other waste treatment processes. However, as shown in Component D, as discharges become large with respect to the absorptive capacity of the environment, waste concentrations begin to build up and quality of the environment is changed. The increasing concentration of wastes in the water, air, and other environmental resources results in lowering the ambient environmental quality of the estuary. The relationship between discharges, concentration, and ambient environmental quality can be shown by an environmental transformation function (ETF) as demonstrated in Component D of Figure 1. The next important analytic step is to translate changes in environmental quality into some estimate of the quantitative impact of reduced environmental quality on human beings and other species which depend upon or utilize estuarine resources. This analysis is shown in Component E.

Component E attempts to relate the concentration of pollutants or the ambient environmental quality shown in Part D into costs to and effects upon the species dependent upon the estuary. An example is the effect of the reductions in dissolved oxygen upon the survival of the species in the estuary. Another example is the impact of increased water temperature during the spawning season on the survival of various species in the estuary. Relationships of this kind are measured in Part E of Figure 1, as damage functions.

If all the information as discussed up to this point is available, then this information can be utilized in a benefit-cost analysis which generates management-relevant information indicating how management of estuaries can be improved in the general public interest. In Component G of the model, information from all of the other modules is combined in order to derive standards for socially efficient (cost-minimizing) management of the estuary.[6] This diagram also suggests other management strategies. The purpose of combining all of this information is to provide management authorities with information on how to anticipate the amount of discharges and how the amount of discharges will affect pollutant concentration and environmental quality. This information on ambient environmental quality and concentration can then be translated into marginal damage functions and marginal treatment cost functions which indicate in the upper right-hand quadrant of Part G, the optimal level of concentration, or, from the lower left-hand quadrant, the optimal amount of discharge into the estuary. On the other hand, it may be possible to use even limited information about the benefits and costs to improve management efficiency (Fisher, Krutilla, and Chicchetti, op. cit.) Alternatively, these optimal amounts of discharges or concentrations can be translated in the upper left-hand component into an optimal emissions charge, or pollution penalty which would have the effect of providing emitters with financial incentives to limit their discharges to an optimal level. As shown in Part G, for any emitter emitting more than an optimal amount of emissions into the estuary, this policy would require his paying an emissions charge that was higher than the cost that he would incur by treating the waste. Conversely, the emitter would not be required to cut back his emissions below the optimal point because the cost of treatment would be greater to society than the amount of damages that would be prevented.[7]

In summary, benefit-cost analysis lies at the heart of the environmental systems model since it pulls together all of the relevant information in order to provide managers with (1) specific information on setting of standards for environmental quality; and (2) information on potential policy instruments for achieving optimal environmental quality. Since the logic of benefit-cost analysis simply asserts that efforts to improve environmental quality should be pursued up to the point at which benefits equal costs, it should be acceptable to both environmentalists and economic developers. These two groups, however, typically disagree strongly on the scope and position of the benefit and cost functions, thus differing upon the optimal level of environmental quality and upon appropriate levels for emission charges.

Even if all the vast amount of information and analysis required for the benefit-cost analysis and for

[6] For additional detail on Component G, see Freeman, Haveman, and Kneese, 1973, who use a similar formulation.

[7] An important technical point to be emphasized is that the optimal amount of discharge and hence the optimal emissions charge will vary between estuaries and indeed, over different tributaries and reaches of the estuary, depending upon varying assimilative capacity as measured by the transformation function in Component A. Therefore, full inter-spatial and inter-temporal implementation of the model would require time series forecasting of each type of economic activity and its associated residuals for each location (Cumberland and Herzog, forthcoming).

the rest of the economic environmental systems model were available and known, there is no assurance that this information and analysis would be used to improve management of the estuary unless certain other institutions and conditions existed. It is first of all essential that appropriate information and educational channels are available for transmitting and clearly communicating the information from the model to the general public and to the decisionmakers Secondly, there must be institutions capable of utilizing the scientific management information. It is also necessary that people understand the effects of their personal lifestyles and values as expressed by their consumption patterns, on the quality and future status of the estuary It is also essential that management institutions have available not only the legal authority, but also adequate financing and the range of management procedures needed to implement management aims.

Any total systems management model must therefore reflect the important role that the public, institutions, and management agencies play in decisions on investment, consumption, government programs, laws, and policies As indicated in Component H of Figure 1, these private and public management institutions then feed back changes in information and priorities into the economic sectors of the model which again affect changes in output, altering its composition and size, and therefore, the generation of wastes and residuals [8] Thus the cycle is completed and the model is closed in a total general equilibrium system

RECOMMENDATIONS FOR IMPROVED MANAGEMENT OF ESTUARIES

The interrelationships between the various components of the economic environmental estuary system proposed here suggest a number of directions in which improved environmental management may be pursued Some obvious points are that the management institution and its geography should be coterminous with the total environmental space of the estuary, embracing all of its tributaries and inputs, as well as its areas of discharge, the total atmospheric environment, and all of the land mass from which waste and discharges are emitted into the estuary. This is a very large order which must be interpreted reasonably, but in general, effective estuarine management will depend upon close control over the environmental emissions into the total system, and successful estuarine management will depend upon the creation of the management institutions appropriate to the task.

The second major conclusion concerning improved estuarine management is that the principal management priority is to offset the market failures which result from the common property aspects of the estuary by establishing an appropriate set of controls which bring the private costs of using the estuary's resources into line with the social costs, thus preventing the abuse and overstress of the estuary.

The third major implication of the model is that a large amount of data, research, and analysis will be necessary to achieve these objectives However, if appropriate environmental quality standards can be established, there are fortunately a number of different management policies and techniques alone or in combination, which can be used to achieve them. One of the most important sets of management techniques is simply the establishment of environmental standards by law, by zoning, or by other regulations and ordinances. Another potentially very attractive set of management policies is the use of emissions charges It can be demonstrated in Part G of the model that establishing an appropriate level of emissions charge is a potentially efficient device for limiting the discharge of residuals into the estuary to the level representing an effective social balance between the demands of economic development and environmental responsibility

One of the most important potential attractions of using an emissions charge is that the proceeds from such a charge could be used to achieve some other objectives of environmental management Often it will be necessary to establish new commissions for estuarine management, particularly when the problem is interstate, inter-county, or interregional. Management institutions need to be financed, and to have an adequate research and information base. The proceeds of a properly designed set of emissions charges in an estuary could be used to finance a management commission and to support the research needed, particularly the interdisciplinary research required to determine transformation functions, damage functions, and optimal environmental standards These funds could also be used for monitoring the release of emissions and enforcing the standards (Cumberland, 1972) Some possible regulations and policies that an estuarine management commission might apply to improve management and to increase public welfare will be examined below. However, there are some potential dangers which should be considered in the use of emissions charges to support an estuarine management commission

One is the hazard of becoming financially dependent upon these funds, and thus developing a vested

[8] The major conclusion of this paper is that the appropriate institutional component for estuarine management is an interregional commission partially supported by emissions charges

interest in perpetuating pollution. Another problem pointed out by public finance theorists is that to the extent that the charges were successful in reducing pollution, they would earn very little revenue, and to the extent that they were successful in generating revenue, their effectiveness in pollution abatement could be debated. The example of accumulation of economic and political power associated with the Highway Trust Fund provides a warning against the potential abuses of automatically setting aside revenues for a specific purpose. However, it must be recognized that economic factors associated with the public goods problem systematically encourage underinvestment in environmental protection, unless special programs are developed. These problems suggest that emission charges might be combined with other environmental control measures as an important but not sole instrument for pollution control.

We have seen that the major task of managing estuaries is to achieve an appropriate balance between economic growth and development and the environmental quality of the estuary. Because of the common property nature of the estuary and the economic incentives of industry to discharge its waste at lowest costs, the primary management task for estuarine management will be to reduce the amount of residuals and externalities imposed upon one set of users by others, and to take a long-run view of the estuary as an ecological unit which must serve the needs of future generations, as well as those of the present.

The achievement of these objectives will call for judicious use of a wide range of management policies and techniques. These could probably best be achieved by management commissions set up as described and given responsibility over the total environmental space of the estuary with appropriate powers of planning, establishing standards, taxing, monitoring, and enforcement. There are many policies and sets of procedures that such an institution might use. Among the most promising would be a comprehensive set of emissions charges on all types of emissions and externalities. These charges, of course, should be related to both the assimilative capacity of the estuary and the damages that would be created by the discharges. It is important to note that these emissions and discharges are not limited to liquid, solid, and gas alone, but that they also include releases of energy in the form of heat, noise, and radioactivity. Some of the most urgent needs for effective improved management of estuaries are sharp reductions in the amount of thermal waste, radionuclides, and noise emission. Stiff charges could be applied to all of these pollutants. The benefits from applying charges to them all would be both to reduce the emissions and to provide financial incentives to the emitter to find improved technologies for reducing future emissions, thus sharing between both polluters and the society the benefits of reduced pollution. Establishing the principal of full responsibility of the emitter to pay for any accidental or other damage created by his activities such as oil spills, chemical spills, explosions, sedimentation damage to water tables, damage to aquifers, and so on, provides a strong incentive to prevention of damage (Cumberland and Fisher, 1974).

However, in addition to emissions charges and penalties, estuarine managers will also need other instruments such as the powers of planning and zoning to protect the wetlands upon which the health of the estuaries depends and to manage inland development which ultimately determines the amount of waste that is discharged into the estuary. In fact, the power of zoning should be extended from land to water resources. For example, increasing numbers of recreationists appear to be adopting high-technology, noise-intensive types of recreation such as water skiing and the use of high-speed water craft, dune buggies, trail bikes, aircraft and helicopters. Because they impose very great dangers, damages, disamenities, and discomfort on other users of the estuary, these activities should be heavily taxed, limited to restricted areas, and permitted in other areas only as contributors to public welfare (emergency vehicles). An appropriate balance between these competing demands can be achieved not only by establishing charges upon speed, noise, and horsepower, but also by zoning certain limited portions of the estuary for industrial, commercial, high-noise, high-speed activities, provided appropriate emissions charges were paid and by excluding these activities altogether from other parts of the estuary, regardless of emissions charges. In effect, the charges could be varied by zone, with an infinite charge for the use of some zones.

One of the most important sources of environmental externalities and estuarine damages is the military sector, and one of the most important opportunities for improving welfare through alternative uses of estuaries is to return some of the vast military holdings of tidewater areas to civilian use. The contribution of military security to society is widely recognized as is the need for certain amounts of secrecy and security in this area, but it should be equally recognized that the environmental costs of military activities are often excessive and unnecessary. For example, currently, military activities have the power to override the planning and zoning authority of local governments, as well as potential estuarine management commissions. The magnitude and intensity of military activities result in their being a major source of congestion, accidents, noise, explosions, thermal release, radiation, and sonic booms, from the operation both of very large types of conventional vehicles and advanced weapon systems. Judging by the dollar value alone of military activity, and not allowing for any increased environmental intensity of military operations and experimental weapons systems, it is unquestionably one of the major generators of environmental externalities in estuarine regions.[9]

In view of the difficulty of local governments and management commissions in regulating military activities, a national policy is necessary in order to minimize their environmental impact and to achieve national efficiencies in geographically locating them in those regions where environmental impact can be minimal. In the long-run it would be desirable to return to civilian use all military properties located in estuaries where civilian activities are widespread. A national policy of returning estuarine based military activities to civilian use and removing military operations to unsettled regions could improve total national welfare through increasing the supply of public goods for recreation. However, an essential element of such a policy should be to offset local economic adjustment problems through compensatory policies, and through careful regulation of the public use of released military bases to exclude pollution-intensive forms of recreation. For example, very little justification in economic theory can be found for providing military recreation centers which favor privileged classes of individuals such as military people to the exclusion of the general public.

Subsidies and program assistance can also encourage creation of public goods which are not sufficiently generated by market processes. Among the activities which are particularly in need of subsidy are recreation, especially for wilderness areas, hiking and biking paths, ecological research areas, protection of critical marshlands, and prevention of shore erosion. Other types of activities for which subsidies might be provided are actual removal of offensive activities, such as pollution-intensive power plants and military bases, as discussed above. Another type of public good worthy of subsidies is historic restoration, such as Williamsburg in the tidewater area of Virginia and St. Mary's City in the tidewater area of Maryland. Subsidies should also be considered for those types of activities which are environmentally beneficial or neutral, such as windmills and solar energy devices.

[9] In the Chesapeake Bay region, military activities dominate major segments of prime air, land, and water resources, creating extensive planned, and often accidental explosions under water, on land, and in the air.

SUMMARY AND CONCLUSIONS

This paper has also emphasized improvement in estuarine management through the creation of estuarine management commissions which are geographically coextensive with the estuary and its total environmental space. This problem is not only economic, but also political in nature and the composition of such management commissions is critical. Once again, recognizing that bias in estuarine management tends to be heavily in favor of excessively rapid economic development and short-run revenue producing activities, the usual economic and political representation of such commissions should also be balanced with participation of citizens' and conservation groups whose long-run views merit at least a hearing. Providing clear channels for citizen participation in environmental management is an essential corrective to the usual problem of concentrated economic and political power used to distribute heavy pollution burdens widely over large populations which then face heavy costs in organizing to protect their welfare.

The national policy on estuarine management should recognize the principle that the federal government establish minimum environmental standards, but that local areas, including estuarine management commissions be permitted to veto local developments and to establish higher environmental quality standards than the federal minimum. The justification for this point of view is not only recognizing local preferences and seeking improvements through permitting local choice, but also encouraging improved technology by establishing very high performance standards at the local level so that would-be polluters have positive incentives to seek cleaner technologies. Such local citizen activity has already resulted in the refinement of nuclear technology and other energy systems. Since market processes usually combine with economic and political power to generate excessively rapid development and intensive overuse of estuarine resources, recent proposals to permit the federal government to override local preferences for nondevelopment, or to require states to set aside energy development areas regardless of local wishes seem inefficient economically, and politically indefensible in a federal system.

A most important part of life cycle planning is recognition of the fact that all residuals should be specified which would be generated by any proposed development through every phase, including exploration, construction, operation, and eventually rehabilitation of the site. Complete life cycle planning based on materials balance concepts would require that the producer specify exactly what inputs would enter into the process, and exactly what ultimate disposition would be made of all of these inputs. Component C of the systems analysis should warn that even treatment is not enough, for treatment processes involve wastes whose ultimate disposition has to be specified and paid for, preferably by the emitter.

Another reason for restraining market-oriented irreversible development is the need for keeping open options for the future. As Krutilla and Cicchetti have emphasized, changing technology plus changing income elasticity of demand for recreation will probably increase the future value of unspoiled recreational resources and reduce the present value of technology-intensive activities (Krutilla and Cicchetti, 1972).

Aesthetic damage to shorelines, skylines, and other estuarine resources is a costly type of environmental pollution. Although the cost may be spread out over a large number of people over a very long period, realistic measurement would indicate a serious decrease in social welfare. For this reason, all of the policy measures discussed above such as charges, controls, and subsidies should be used to discourage large physical intrusions of any kind and to subsidize protection of natural landscapes. Examples of visual pollution are bridges and power lines which appear to diminish the magnitude and majesty of a body of water or a distant skyline. Where such facilities are regarded as essential, the alternative of using tunnels rather than bridges and of undergrounding powerlines and pipelines rather than permitting them aboveground should be encouraged by economic and other incentives.

Finally, an important feature of estuarine management commissions would be their research capability. These institutions could advance the art of environmental management through continual research on damage functions as indicated in the systems model and by giving the regional commissions the capability of forming independent estimates of the impact from proposed activities. One promising format for the research arm of such estuarine management commissions is the Chesapeake Research Consortium in the Chesapeake Bay region (1971–1972). Another opportunity to finance and encourage environmental research and public goods activities is through the sea grant program, under which local institutions can be encouraged to develop the multidisciplinary research capabilities called for in Figure 1 for estuarine management, research, and policy formation.

Because of the vulnerability of our estuaries, developing the knowledge, skills, and institutions needed to reverse the damage now being done to them will not be an easy task. However, the lesson to be learned in improving our management of these vital resources will be a crucial step in mankind's belated efforts to recognize his responsibilities for long-run protection of his total environment on earth. The systems analysis presented in this paper suggests that establishment of interregional, interdisciplinary management commissions, financed partially through emissions charges, and with broad powers to levy these charges, conduct research, monitor environmental quality, and control land and water use is a promising institutional approach to the protection and management of estuaries.

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ESTABLISHING THE ECONOMIC VALUE OF ESTUARIES TO U.S. COMMERCIAL FISHERIES

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ABSTRACT

The economic importance of estuaries is assessed in their supportive role of the U.S. commercial fishing industry. Economic welfare concepts are related to major phases of the fishing industry, and empirical estimates of these values are surveyed in the literature. The exvessel price of landed species is cited to be a conservative estimate of net benefits realized by all phases. The literature survey reveals that most economic studies of fishery benefits are conducted without any apparent knowledge of valid welfare concepts. This gap between empirical and theoretical constructs must be eliminated if economic values are to be plausible and meaningful.

INTRODUCTION

The estuaries of the United States have traditionally nurtured a significant portion of the total commercial fish catch. Records dating back to the early colonization of America reveal a close link between economic development and estuarine resources. For New England pilgrims facing cold winters, clams and mussels were the major diet during the periods of food storage. Some communities along the Atlantic coast depended almost entirely on the fishing industry and related activities, such as shipbuilding and the construction of marinas. Identified as the most naturally fertile environment in the world (Odum, 1961), estuaries provide a haven for fish and shellfish at various stages of their life cycle. It is estimated (Stroud, 1971) that, depending upon the geographic region, 65 to 90 percent of domestic fish landings are comprised of estuarine-dependent species. Furthermore, there is the enormous potential of increasing usable catches from estuaries by mariculture, improvement of fishing efficiency, and increased harvest of underutilized species.

Despite the recognized importance of estuaries to the economy and welfare of society, these areas are often exploited for dredging and landfill operations that permanently imperil fishery resources. These damaging activities are usually justified in monetary terms for industrial, residential, or commercial development purposes.

The conservation of fish habitat, on the other hand, is more difficult to evaluate in economic values. Yet without such an evaluation, competing water uses will continue to be the primary factors considered in estuarine development cost/benefit analyses. It is therefore to the net benefit of society that guidelines be established to achieve a full consideration of the values of fisheries. Without the development and wide application of such guidelines to coastal zone decisionmaking, the Nation will continue to lose segments of its estuaries to residential and industrial development, with corresponding declines in fisheries stocks (Roberts, 1974).

This paper surveys methods to quantify the economic benefits of commercial fishing and then relates them to empirical studies of specific estuaries. The following section reviews current statistics of U.S. commercial landings and the relative importance of estuaries. The next section outlines the theoretical basis of welfare economics, and then applies these concepts to benefit estimation at the fish catching, processing, and marketing phases. Distinctions are recognized between direct benefits of the fishing industry and indirect benefits to the regional economy.

Following this is a summary of published values of estuaries throughout the nation and an economic assessment of fishery losses from marine pollution. In the next section the various problems of benefit assessment are discussed as they affect the accuracy or credibility of empirical values. To conclude the paper, specific recommendations are made for a comprehensive benefit evaluation of estuarine-dependent fisheries and for management policies that fully recognize these values in coastal zoning decisions.

ESTUARINE-DEPENDENCE OF FISHERIES

In 1973 the total value of reported commercial fish landings in the United States was more than $900 million (National Marine Fisheries Service, 1974) At least two-thirds of that amount is derived from estuarine-dependent species (McHugh, 1966) [1] While much essential biological information remains to be acquired on habitat dependencies, there is a general consensus among fisheries experts (Stroud, 1971) that the following commercially important species spend at least part of their life in the estuarine zone· black sea bass, bluefish, clams, (all soft clams and some hard clam species), crabs (except king and tanner crab), croaker, black drum, red drum, American eel, flounder, lobster, menhaden, mullet, oysters, porgie, puffer, salmon (chinook, coho), seatrout, shrimp, spot, steelhead, striped bass, sturgeon, tarpon, tautog, and weakfish

Published statistics on the exvessel value of particular species give strong testimony on the significance of estuaries to the commercial fishing industry and the American economy as a whole (National Marine Fisheries Services, 1974) Of the 10 most valuable species landed in 1973, eight are directly dependent on the estuary and represent over $660 million in dockside revenue. This figure does not include the value added (i.e., revenue less raw material costs) from the processing, wholesale, and retail sectors.

While the literature on most commercially important estuarine-dependent species has identified the unique life-supporting role of estuaries, there is little quantitative information on total standing crops of particular species (Clark, 1974) As a result, fisheries scientists are unable to predict with confidence just how much estuarine acreage is necessary to maintain existing fisheries at any level of catch effort. This situation greatly complicates cost accounting of commercial fishery stocks which are threatened by estuarine degradation.

Mariculture

The farming of marine animals in the U.S. estuarine zone is not as yet practiced to any appreciable extent (other than perhaps the Atlantic coast oyster industry) After more than a decade of intensive public and private research on this topic, there still are major economic, legal, and technological barriers in this country to establishing a viable aquaculture industry (Gates, 1971). (In certain Asian and European countries, on the other hand, the rearing of finfish and certain types of shellfish is well established) Efforts to raise salmon in estuaries of the Pacific Northwest are hampered by high costs, while research attempts to raise shrimp along the gulf coast are in the preliminary stage but do look promising for the future Should these efforts meet with success, however marginal, they will add yet another dimension to the value of the estuary In cases where conflicts arise between mariculturists and natural fish harvesters, detailed management strategies will be needed to accommodate both interests at some socially optimum combination

THE CONCEPTUAL FRAMEWORK

The economic benefit of a resource is the gain in real income or consumer satisfaction realized by the use or consumption of that resource. However, many benefit estimates are made without a valid economic rationale The assumptions and techniques used in estimating benefits need to be checked against sound, economic theory to determine their validity

The concept of benefits, as proposed in this study, conforms to basic ideas of welfare economics By definition, the gross benefit of estuaries in terms of commercial fish is the maximum amount that society would pay for the actual or potential yield of fish In a socially optimum allocation of resources, this amount will at least equal the value of all goods that society has foregone in order to obtain the output from the fishing sector According to economic terminology, this foregone value is called the opportunity cost of fishing and should be subtracted from gross benefits to estimate the net benefits Net benefit is the willingness-to-pay value after total production costs are subtracted.

The fishing industry is comprised of vertically integrated phases that include the catching of fish, the processing and distribution of fishery products, and retail marketing to the final consumers (Bureau of Governmental Research and Service, 1969). Each of these activities contributes to the net benefits of commercial fishing The net benefit of each sector, i.e , the value of the output of the sector after subtracting total production costs, is also known as the value added by that sector The following remarks pertain to the most valid guidelines of assessing the net benefits at each phase

The Catch Phase

Fishermen constitute the most fundamental link in the chain Most benefit estimates in the literature

[1] While a two-thirds ratio is the most commonly quoted figure, several estimates range as high as 75–90 percent, with the upper figure cited for catches along the gulf coast (Newsletter, 1974, Atlantic States Marine Fisheries Commission, 1966, Stroud, 1971)

narrowly focus on fishing revenues. It is commonly assumed that net benefits are calculated as the difference between dockside catch value and fishing costs of capital, labor, and other input factors. Unlimited entry into the fishery grounds entices too much capital and labor input in the industry. As a result, net benefit calculations, the difference between value of catch and fishing costs, are often zero or negative in the long run. The invalid implication of this logic is that commercial estuarine fishing does not enhance social welfare.

An alternate approach has been suggested (Crutchfield, 1962) to overcome this dilemma. The rent or value of the resource should be calculated under the ideal situation wherein only the most efficient fishermen have access to fishing grounds. Net benefit is then determined at the economic optimum level of output given the least cost strategy of production. This implies a reduction in the size of the fishing fleet and manpower requirements, which in turn would allow the "excess investment" to be utilized in more beneficial sectors of the economy.

While this approach can provide a reasonable empirical value, it neglects certain welfare impacts by not quantifying all of the benefits and should be modified accordingly. For example, the excess investments due to free entry may be indicative of society's preference for a larger fishing fleet and its protection of one of America's oldest labor markets. Any attempt to dislodge these excess investments could induce drastic changes in the prosperity of fishing ports, the displacement of fishermen and their families, and a reduction of scenic amenities provided by picturesque fleets and colorful old fishermen tending to their daily chores.

On the other hand, it could be contended that excess investments in fishing are not preferred; rather they are forced upon society as a result of an historical misallocation of resources. This resource immobility accounts for a portion of the potential rent, and, if at all possible, should be deducted in the estimate of net benefits.

Some resource analysts (Gosselink, 1973; Hite, 1973) claim that the entire landing value of fish should be imputed to the net rent of estuarine areas, as an indication of "the dependency of jobs and commercial fisheries on the existence of these free resources." This assumes that capital and labor commitments to the fishery cannot be shifted to other uses. In the short run, this assumption seems valid for some fisheries where the commercial fishermen are quite old and entrenched in their jobs despite relatively low incomes, and where the conversion of boats and fishery equipment into other uses is technologically impractical. Yet over the long run, these resources will eventually flow into more profitable uses. As old vessels are retired, the materials and labor necessary to replace them will be used in other industries. Fishermen are less likely to find new employment, although this is not a universally accepted opinion.[2]

In a meeting (McQuigg, 1971) of Canadian scientists, it was concluded that landing price may significantly underestimate net benefits aggregated over all phases of the fishing sector. Direct benefits include current net rent to fishing, processing, and marketing profits. Indirect benefits include the additional income and employment generated, if any, in coastal communities in other industry and service sectors as a result of the commercial industry and fishing. Another analysis (Bell, 1974), of international fishery values, claims that the exvessel price is an adequate proxy for net benefits to the consumer. Unlike the Canadians' emphasis on producer benefits, this conclusion pertains exclusively to welfare impacts from the retail market as discussed later.

The Processing and Distribution Phase

Intermediate activities of the fishing sector begin with the wholesalers who purchase the catch at dockside and then extend to include processor, distributors, and the retail markets. Net benefits attributable to this phase are usually ignored in the literature because of the lack of readily accessible data. To date, few estimates of such values have been attempted. It assumes that the total value added by processing and wholesaling sectors reflects net welfare (Carley, 1968). Whether value added represents a good approximation to net benefits remains to be proven. According to economic theory, monetary benefits are determined by the excess profits or producer surplus earned by this phase of the industry. The magnitude of this benefit depends upon the profit-making potential of the industry.

The number of processor-wholesaler firms has declined in recent years and those remaining have broadened their sphere of influence and increased their profit-making potential by handling more fishery products and adding restaurants or retailing facilities to their investments. Profit-making potential is also obtained by controlling a large enough share of the market to influence prices. Interferences

[2] For example, a recent study (Strang, 1974) on charter boat fishing in the Great Lakes found the age distribution of fishermen to be bimodal, with a significant portion over 50 years old and another concentration in their twenties. The latter group is particularly mobile, and could thus find employment elsewhere, in view of current opportunities in this country for non-professionals in skilled and unskilled jobs.

with the price mechanism have been cited (Hite, 1973) for the tuna canning sector, where unit landing prices are set prior to the catch by a cooperative of vessel owners and fishermen Such activities could introduce excess profits, which nevertheless, should be included as a component of net benefits

Retail Sales Phase

The value of fishery resources depends on two sets of complex market forces The above discussion broadly recognizes the supply side including the cost of harvesting, processing, and distribution of fish products There is also the demand side which takes into account the consumers' preference for fish and shellfish The intensity of this preference is reflected in the prices that individuals are willing to pay for various commodities, given current or foreseen consumption alternatives in the market Conceptually, net benefit to consumers is the difference between what they pay for fish and fish products and its value to them This concept is referred to as consumers' surplus

The demand for any fishery product depends upon individual tastes, level of income, and prices of that product as well as the price of related goods. The U S per capita consumption of fish and shellfish has remained virtually constant in this century indicating that tastes have remained relatively constant In the past, the quantity of fishery products purchases responded greatly to price changes. However, recently the change in amount purchased in response to a change in price has been relatively small On the other hand, the quantity of fishery products purchased has responded more to changes in income than it ever has before Of course, these observations vary according to the species (Wong, 1970)

Consumer benefits from the demand for industrial fish are more difficult to quantify, since there are essentially two levels of retail purchases In the industrial market, such rawfish as menhaden and anchovies—both marketed almost exclusively as inedible—are sold directly to feed-fish processors Fish meal, which then becomes part of the feed for poultry and livestock, is eventually converted into final consumer products ranging from pet food to glues How to apportion these final product benefits among such constituent inputs as fish meal is an unresolved issue

A related problem involves apportioning total consumer benefits from all fishery products among specific species or specific estuaries If economic values are to be assigned to individual estuaries, the fraction of the total supply must be determined

Besides consumers' surplus which pertains to current demands, there is also "option value" associated with the desire for consumption at some time in the future This benefit is the price an individual is willing to pay now to preserve his option of consuming a product in the future

Because option value is not included in current market prices, its contribution to fishery values is either dismissed or neglected by many decision-makers While it may indeed be difficult to derive the values, some attempt should be made to include them in a benefit assessment The omission of option value results in an underestimate of the value of a fishery or estuary, which could seriously imperil attempts to preserve fish habitat for future use

In recent economic literature (Abel, 1974), other types of benefits have also been identified, although their empirical valuation remains to be investigated. One such measure is "existence value," which is an individual's willingness to pay for society's use or conservation of a resource, even if he does not intend to use it

A related type of benefit follows from an individual's desire to make the resource available to future generations rather than to himself This "bequest value," as it is appropriately called, is similar to the willing of estates and large fortunes by parents to their children These benefit concepts should affect future income streams from estuarine resources, but just how much they add to current values has been neither demonstrated nor even conjectured

Local and Regional Impacts

There are several approaches to assessing the economic impacts of commercial fisheries The above discussion of measured and non-measured benefits pertains to the direct gains of personal welfare attributable to the production and (actual or optional) consumption of fish resources Another economic impact is the indirect or secondary effect on the economy of a local area or region These impacts result when additional income and employment are generated by the fishing industry in other economic sectors such as service industries and retail stores

Policymakers are rightly concerned about secondary benefits, since one of their common goals is to protect and encourage economic growth within their political jurisdiction Employment can potentially be stimulated and tax revenues increased within regions that have an expanding fishing industry

The magnitude of the secondary benefits depends upon the size of the region as well as the structure of the economy and whether underemployed resources are available there. In general, the smaller the geographic area, the less likely it is for a region to be self-sufficient in many products. Hence, expenditures will take place outside the region and the benefits will be correspondingly reduced. From the regional perspective, it follows that sales or purchases providing additional income to one area may represent a loss to another. For the nation as a whole, however, the local and regional impacts should be excluded from net benefit calculations as they will, by definition, cancel each other. To local and regional decisionmakers, however, this information is essential in weighing alternative plans to determine priorities for economic development.

Some economists (Prest, 1965) argue that secondary benefits should not be counted as a gain to society. They contend that in a competitive economy, these benefits are reflected by the price of the original good. That is, as the secondary effect of the good increases, its price should rise in corresponding fashion. This assumes perfect factor mobility, wherein gross expenditures for fish resources can be easily shifted to other resource demands. In a full-employment economy there are many opportunities for long-term resource shifting. For the fishing industry, this assumption may not be completely valid in cases where fishermen are immobile or cannot find jobs elsewhere.

EMPIRICAL RESULTS

Published estimates of the economic value of estuaries date back into the 1950's, although most values have appeared within the past several years. Recently the work of Odum and fellow researchers (Gosselink, 1973; Odum, 1968; Odum, 1960) received widespread attention because of the large magnitude of estimates[3] for estuaries along the south Atlantic and gulf coasts. But the most extensive evaluations have been conducted by Massachusetts' Division of Marine Fisheries (Chesmore, 1972; Chesmore, 1972; Chesmore, 1973; Jerome, 1969; Jerome, 1973; Jerome, 1968; Jerome, 1966; Jerome, 1965), one of whose charters is "to establish more precisely the values and relative importance to the fisheries of particular areas."

In Table 1 the economic values of various estuarine areas are compared, and are adjusted to base year 1973 by an exvessel fish and shellfish price index (National Marine Fisheries Service, 1974). Values along the Massachusetts shoreline are based on mean high water levels, but would be 20–100 percent larger if calculated for low water conditions due to the change in total estuarine surface acreage. Moreover, they reflect catch value divided by the total area of surface water. In a highly productive subarea of the San Francisco Bay estuary (Howard, 1973), the yearly revenue for oysters exceeds $500 per acre (in 1973 dollars). It is also interesting to compare values for the same estuary, as reported in different references. Along the Alabama coast, for instance, two estimates differ because of the year in which revenues were observed and the specific fishing grounds under consideration. In Delaware Bay, unit values differ by type of species. Other factors affecting the magnitude of estuarine values are discussed later.

The predominance of estimates along the Massachusetts and gulf coast shorelines substantiates the fact that fisheries here are largely estuarine-dependent. In California, however, more than two-thirds of past coastal marshland has been replaced by land developments. In 1899 the catch of oysters in San Francisco Bay exceeded $2,000,000 (in current money) but gradually declined to barely 0.3 percent of this amount by 1973. Western fisheries have thus moved into deeper waters, so that estuaries are seldom valued. In the Pacific Northwest, anadromous fish species contribute to estuarine values, but they spend most of their lives in ocean waters or spawning streams.

A description of the catch in these estuaries indicates the relative importance of the different species. While shellfish provide the major source of income, there are also instances where eels, bait worms, and finfish are economically quite valuable. A comparison of the estimates in the Merrimack River Estuary, Mass., shows that clams rank first in value by far, although potential sales of bait worms are unexpectedly high at more than $250 per capitalized acre. Even marsh grass has an economic value since it supports the growth of an oyster community although no attempt was made in this report to impute a value for it.

These annual values conceal the long-term contribution of estuarine resources to social welfare. For renewable resources such as commercial fish, economic returns should be comprehended over a sufficiently long time horizon. To compare them with nonrenewable resource values over a single (current) year biases the results in favor of current returns. Consequently, a capitalized value of each estimate is also calculated in Table 1.

Capitalized value represents the amount of capital, in real dollar terms, which must be invested at a

[3] According to these authors, natural tidal marshes along the gulf coast typically have annual returns of $3,000 or more per acre. But only $100 of this amount is related to fisheries, the bulk due to waste treatment costs avoided because of the natural assimilative capacity of the estuarine mixing zone. But intensive aquaculture could increase the contribution of fisheries to as much as $1,000.

Table 1 —Economic values of estuaries to commercial fishing

Estuary	Annual Per Acre Value	Year	Description of Catch	Per Acre Capitalized Value in 1973 Prices	Estuary Area in Acres
Essex Bay MA (Chesmore, 1973)	$256 00	1969	Lobsters and Soft-Shell Clams	$4,104 00	1,261
Entire GA Estuary System (Gosselink, 1973)	9 00	1965	All Commercially Valuable Species Landed in Georgia	218 00	393,000
DE Bay Estuary (Shuster, 1971)	170 00	1956	Oysters	3,990 00	8,000[a] (actually fished)
DE Bay Estuary (Shuster, 1971)	1 18	1956	Oysters	11 80	2,560,000[a]
San Francisco Bay Estuary (Howard, 1973)	563 00	1971	Oysters	5,630 00	4,000[b] (actually fished)
San Francisco Bay Estuary (Howard, 1973)	12 00	1971	Oysters	80 00	300,000[b]
San Francisco Bay (Skinner, 1962)	15 00	1956	Mixed Finfish	396 00	300,000
Entire LA Estuarine System (Gosselink, 1973)	27 00	1970	All Commercially Valuable Species Landed in Louisiana	473 00	2,200,000
Entire FL Estuarine System (Gosselink, 1973)	41 00	1970	All Commercially Valuable Species Landed in Florida	718 00	1,050,000
Beverly-Salem Harbor Estuary, MA (Jerome, 1973)	37 00	1965	Clams, Lobsters, Bait Worms, Finfish	894 00	8,541
Mobile Delta, AL (Beshears, 1959)	2 00	1959	Mixed Finfish, Bait Worms, Shellfish	51 00	50,000
Mobile Bay AL (Beshears, 1959)	13 00	1958	Shrimp and Oysters	286 00	275,000
Corpus Christi Bays, TX (Anderson, 1960)	15 00	1958	Mixed Finfish and Shellfish	370 00	228,541
Merrimack River Estuary, MA (Jerome, 1965)	45 00	1964	Mixed Finfish and Shellfish	977 00	3,050
Dorchester Bay Estuary, MA (Chesmore, 1972)	62 00	1967	Lobsters and Soft-Shell Clams	1,240 00	5,293
Galveston-Trinity-East Bay Estuary, TX (Stroud, 1970)	58 00	1967	Mixed Finfish and Shellfish	1,317 00	333,000
Parker River-Plum Island Estuary, MA (Jerome, 1968)	92 00	1965	Crabs, Clam Worms, Clams, Lobsters	2,158 00	3,581
Annesquam River-Gloucester Harbor Estuary (Jerome, 1969)	116 00	1965	Mixed Finfish and Shellfish	2,817 00	2,237
Hingham Bay Estuary (Iwanowicz, 1973)	26 00	1970	Lobsters and Clams	455 00	7,272
Entire VA Estuarine System (Wass, 1969)	77 00	1968	Mixed Finfish and Shellfish	1,545 00	177,073
Coastal Estuaries Hampton-Seabrook, NH (Fogg 1964)	33 00	1963	Clams, Crabs, Lobsters, and Sea Worms	816 00	3,200
Quincy Bay Estuary, MA (Jerome, 1966)	9 95	1968	Clams, Lobsters and Crabs	100 00	7,313
Waquoit Bay-Eel Pond Estuary, MA (Curley, 1971)	106 00	1968	Quahogs, Bay Scallops and Soft-Shell Clams	100 00	7,313
Lynn-Saugus Harbor Estuary, MA (Chesmore, 1972)	28 00	1968	Lobsters, Soft-Shell Clams, Sea Worms	562 00	6,317
Tampa Bay Estuary, FL (Taylor, 1968)	64 00	1965	Mixed Finfish and Shellfish	1,547 00	3,500
Apalachicola Bay Estuary, FL (Federal Water Pollution Control Administration, 1969)	33 50	1967	Mixed Finfish and Shellfish	810 00	64,000
Great South Bay Estuary, NY (Federal Water Pollution Control Administration, 1969)	50 00	1965	Clams	1,113 00	4,500
Atlantic Coast Estuaries (Stroud, 1970)	71 00	1965	Mixed Finfish and Shellfish	2,716 00	2,328,423
Narragansett Bay Estuary, RI (Federal Water Pollution Control Administration, 1969)	31 00	1965	Mixed Finfish and Shellfish	749 00	108,800
Penobscot Bay Estuary, ME (Federal Water Pollution Control Administration, 1969)	113 00	1965	Soft-Shell Clams	2,512 00	6,645
U S Estuaries (1973)	21 00[c]	1967	Mixed Finfish and Shellfish	477 00	29,300,000

[a] The per acre value of $3,990 represents the capitalized worth of only the oyster-producing grounds of the estuary, which in 1956 totaled only 8,000 acres Taking the entire 2,560,000 acre area of the estuary into account and averaging the total oyster catch value across the entire acreage results in the smaller per acre value of $11 80

[b] The per acre value of $6,630 represents the capitalized worth of only the oyster-producing grounds of the estuary, which in 1971 totaled 4,000 acres Taking the entire 300,000 acre area of the estuary into account and averaging the total oyster catch value across the entire acreage results in the smaller per acre value of $80

[c] The unit value is derived by the authors as the ratio of total U.S dockside revenue (National Marine Fisheries Service, 1974) adjusted for estuarine-dependency, to the total area of U S estuaries (Federal Water Pollution Control Administration, 1969)

Note All values reflect dependency factor of 2/3 of total catch given market interest rate in order to return a perpetual dividend equal to a fixed annual net profit. For example, if a particular estuary provides $100 in net social benefits per year from its fishery resources, then its capitalized value at a market interest rate of 10 percent is $1,000.[4] Capitalized values in Table 1 assume an interest rate of 10 percent as the fair market value of current capital investments. The authors believe this accurately reflects the opportunity cost of capital investment with respect to current market conditions in the private sector. It is not our intention to debate which interest rate may be the more accurate but rather to present the concepts of benefit estimation and some examples of empirical studies of the worth of an estuary as a natural resource.

Once the capitalized landed revenue of the fisheries resource has been calculated, one further step is necessary to derive the net economic rent of the resource. Net economic rent is defined as the difference between the costs of the factors of production (capital equipment, labor, and the returns to management) and the landing revenue. Since the (capitalized) values in Table 1 reflect not only the net economic rent of the resource but also the returns to the factors of production, they overestimate the actual value. Therefore, the share of the landed revenue accruing to the cost factors should be subtracted from the total landed value to arrive at the net worth of the actual fisheries resources. From previously cited remarks, however, some economists prefer to use the total capitalized value as a conservative estimate of consumer surplus, which they consider as the most valid indicator of social benefits.

Statistics on the costs incurred by commercial fisheries are rarely published, and therefore must be estimated in an appropriate manner. A discussion of the methodology and of the difficulty of cost calculations is included in the text whereby given the necessary data and cost factors a more accurate estimate of the net resource value could be undertaken. It is hoped that the issues raised in this paper will eventually result in just such an investigation in the future.

DAMAGES FROM POLLUTION

The biological degradation of estuaries by man-made waste discharges is well documented and is reviewed elsewhere in this report. Economic losses, on the other hand, are seldom published. The inherent difficulty of assigning welfare values to these losses, aside from the more basic problem of estimating natural productivity declines, accounts for large uncertainty in the estimates.

Most values of commercial fishery losses from pollution focus on localized problems, although there are at least three national estimates. Practically all values pertain to foregone landing revenues rather than net welfare impacts. Table 2 depicts the dollar value and geographic area of these losses (Tihansky, 1973). Fish kills are evaluated by assuming that each counted fish is worth $0.10, which is generally a very conservative value for mature commercial fish. Retail losses in Puget Sound are converted into landing price equivalents by assuming a 3:1 ratio of their relative magnitudes. The "Red Tide" scare in New England not only reduced lobster and fish sales by several million dollars but also caused unemployment of fishermen, who would have earned $91,000 in 1972. Other estimates in the Table illustrate the wide variation of effects of waste discharges on a number of estuarine-dependent species, ranging from clams to salmon. In Galveston Bay, Tex., the loss of oyster sales translates into $60 per acre (in 1971).

Table 2.—Estuarine fish losses from water pollution, 1970

Area	Damage ($1,000)	Species Affected
Boston Harbor, Mass.	$5,000	Clam
Chesapeake Bay	8,000	Menhaden
	1,860	Other Finfish
	1,090	Shellfish
Columbia River Mouth	865	Salmon
Galveston Bay	1,930	Finfish [1]
	15	Oyster
Long Island Sound	1,000	Oyster
	225	Clam
Maine Coast	5,000	Clam
Narragansett Bay	1,000	Oyster
Portsmouth, N.H.	2,600	Clam
	125	Oyster
Puget Sound	1,200	Oyster
Raritan Bay, N.J.	8,500	Shellfish
San Francisco Bay	2,600	Shrimp
	2,250	Oyster
	170	Clam
	6,750	Bass, Shad, Salmon [2]
Tampa Bay	2,650	Finfish

[1] Potential loss from oil spills.
[2] Potential loss from inland drainage.

[4] This calculation can be easily derived from the capitalized value formula, $C = V/i$, where C is equal to the capitalized value; V, annual profit, and i, the interest rate. Thus by holding V constant, C will vary inversely with the size of the interest rate. An unrealistically low interest rate, that is, one not reflecting the real rate of return on capital in the market place, would produce a relatively higher capitalized value and overestimate the real worth of the resource.

An estimate not included in the table was the loss of oysters from shellfish area closures in New Haven Harbor, Conn. The foregone cost of small, seed oysters amounted to $578,000 in 1967, but upon maturity they would yield a large potential income of $6,688,000. Annual revenue losses provide an incomplete perspective of total damages. Over the past 65 years, environmental changes along the Connecticut coast have caused declines in shellfish production totalling more than $1 billion (Wong, 1970).[5] Furthermore, the initial effects on decreased fishermen's wages are multiplied throughout the state economy by factors typically between 5 and 10.

National estimates are based on the proportion of shellfishing areas closed by pollution. One study (Bale, 1971) estimates total annual losses of $12 million. This assumes that only clams and oysters are affected since they are immobile and harvested primarily within bays and estuaries. Another analysis (Council on Environmental Quality, 1970), however, assumes that all shellfish including lobsters, shrimp, and crabs are affected by contamination. Its estimate is $63 million based on current closures of one-fifth of the nation's shellfish beds and a corresponding loss of potential revenue. These values assume, contrary to economic theory, that prices remain constant despite large shifts in resource availability. A more recent approach (Tihansky, 1973) measures damages as the consumer surplus foregone by the above shellfish supply losses due to contaminated waters. The national estimate ranges from $24 million for clams and oysters to $38 million if finfish are added to this list of affected species.

FACTORS AFFECTING THE ESTIMATES

Any monetary estimate of estuarine (or fishery) values should be explained with respect to its empirical assumptions. The magnitude of values is a function of a number of determinants, ranging from the extent of fishing grounds to the time span over which the economic impact is calculated. The following factors contribute significantly to these estimates.

Definition of Estuary

The geographic extent of an estuary determines the expected magnitude of catch within its boundaries. While most definitions of an estuary are easily interpreted, there is a lack of unanimity on the most logical choice. Classical opinion holds that estuaries are restricted to the outflow of rivers in a tidal sea, but more recent definitions include non-tidal areas so long as the river water noticeably dilutes sea water (Idyll, 1967; McHugh, 1967). The extreme description extends beyond these concepts to include all waters immediately bordering the ocean coastline. But most studies reject the extreme notion in favor of one of the other viewpoints.

Location of Catch

Relatively few fish or shellfish species appear to remain in estuaries during their entire life span. But at least two-thirds of the total catch near the U.S. shoreline spend at least part of their lives here. In some cases, the estuarine habitat serves as a spawning ground, but more frequently it is a nursery ground, densely populated with juveniles and young adults. Estuaries can also provide nutritional value and food sustenance for temporary residents, and they act as the intermediate area through which anadromous (and catadromous) species journey between ocean and freshwater spawning grounds.

Estuaries also have an indirect value of supporting species in offshore water. Rich nutrient loads from the marshes are transported out to sea by tidal flow and ocean current. In addition, estuarine-nursed shrimp and other life forms low in the food chain are an important source of protein and food for a great many predators, including fish. Unfortunately, this valuable function of translating the richness of estuaries into directly consumable resources cannot be quantified without an almost prohibitively expensive research program tracing the flow of energy in a huge ecosystem. In the literature there is a general consensus that all estuarine-dependent species should be included in the value of estuaries, but at least one reference (McHugh, 1967) suggests a downward adjustment of this total to reflect only the biomass added by the inshore region. In no instance is the indirect food-supportive role of estuaries evaluated in any benefit study.

Temporal Aspects of Catch

To obtain a reliable estimate of the abundance of estuarine-dependent fish is most challenging. Species composition and population densities vary by degrees of salinity, temperature, and other physical aspects of the estuary as well as by season or even by a multi-year period. Catch volumes are likely to be higher when species are relatively abundant, but this is not always true. The type of fishing gear used, the ability of fishermen to locate potential catches, the degree of fishing effect from the sport

[5] This estimate is derived as the sum of lost revenues over a 60-year period beginning in 1900. On an annual basis, therefore, the average loss is approximately $15 million.

fisheries, and political restrictions on the availability of fishing grounds are important parameters in the production function. Occasionally, mass mortalities and dramatic fish kills unpredictably alter catch statistics as well.

The problem therefore is to ascertain the "typical" catch rate or other suitable measure of the abundance of commercial species. Most yield estimates in the literature are based on current conditions. But this time frame could lead to biased answers, if the catch was abnormally low during this period or, at the other end of the spectrum, was higher than the mean. In regions where wide variations in catch have been recorded, benefits should be estimated for low and high volumes in addition to the mean or most likely level. The assumptions underlying this range of estimates should be clearly stated.

Unreported Landings

Catch statistics by themselves may not indicate the total volume of fish caught for commercial purposes. Frequently, unwanted fish are discarded back into the fishing ground, while other species or aquatic specimens unfit for direct human consumption may be sold as bait or as a protein supplement processed in various food products. Reported landings represent a minimum for still another reason. Private fishermen fail to report an unknown quantity of catch, which serves as food in their homes or possibly is sold by them locally. In some estuaries this contribution could be very significant. Further, the contribution of U.S. estuaries to foreign catches is uncertain. Assessing the net worth of these landings poses an additional problem because of the different markets and varying conditions under which they are sold. It is conjectured in Louisiana, for instance, that at least 50 percent of the annual shellfish is so destined (Murray, 1974). The relative share of unreported landings is believed to be large in other states as well, although fisheries experts are generally unwilling to estimate this magnitude.

In view of the likely importance of private catch, a confidence interval of benefits should be evaluated for any estuary. The lower bound estimate should reflect reported statistics, while the upper one shoulc include a "guestimate" of catch aggregated over all unreported but commercially-related sources. Of course, the market price of reported landings may be quite different from the economic value of private catch (which need not be processed and distributed, if the fish are consumed directly at the fishermen's residence). Unit benefit values (per fish caught) should thus be sensitive to these market alternatives.

Price-Income Effects

Economic benefits of fishery resources exist only if there is a demand for their consumption or preservation. Because fisheries must deal with a relatively fixed (but renewable) resource, it is especially urgent in light of population growth that the economic impact of demand pressures be predicted. Practically all demand analyses reveal the basic importance of price and income. Since consumer surplus is derived from demand curves, these determinants have a major effect on benefit values over time.

Historically, the consumer has been sensitive to the price of fish products, but with rising incomes this reaction has become far less pronounced. Luxury foods, such as shrimp and salmon, now appear frequently in many households. These responses imply a generally low price elasticity but a high income effect on demand. In benefit calculations over future time streams, therefore, it is important that these responses be considered. If there is reason to suspect, for example, that projected inflation rates will lower real income, demand curves should be adjusted accordingly so that consumer benefits (surplus) can be predicted more accurately.

Level of Optimal Catch

The biological role of estuaries in perpetuating fishery resources is as important to benefit calculations as the impact of consumer preferences. For some finfish and shellfish species, supply shortages are curtailing potentially larger demands for these products by continually pushing up their market prices. On the other hand, there are many underutilized species that could provide additional sources of nutrition to consumer diets.

There are several measures of the supply variable, each of which uniquely affects the magnitude of net benefits. Biologists usually seek to estimate the level of fishing associated with the maximum sustainable yield (MSY), such that the annual gain in species population from recruitment and growth is just offset by natural mortality and fishing catches at a population level that maximizes catch. But economists (Fry, 1962) usually argue that since commercial fishing is motivated by profits rather than physical catch, the more appropriate objective is the maximum economic return to the fisheries and the regional economy. In actual situations, neither of these goals is pursued. Instead, the free entry nature of fishing encourages inefficient use of input factors and through overcapitalization and overfishing, has frequently reduced profits (resource rent) to zero.

All of these yields are likely to fall short of maximizing overall welfare impacts of fishery resources. The MSY and free entry solutions obviously are not oriented toward such an objective. But even the economic rent-motivated approach may be misleading, as it ignores various social values of the fishing sector (since they elude simple quantification). More importantly, it represents a partial equilibrium solution by neglecting optimal benefits in the processing and distribution sectors. Some analysts (McHugh, 1970) conjecture that maximal catch rates might confer advantages on the latter sectors by increasing economies of scale in production. Whether this hypothesis is valid remains to be tested empirically. Until then, net benefits should be calculated twice, bounded above by the MSY solution and below by the optimal net social return.

Several case studies can be cited on the economic returns expected at various levels of fishing effort. A detailed analysis (Gates, 1973) of the New England yellowtail flounder fisheries concluded that the current free entry situation nullifies the total net rent to domestic industry (although net earnings differ by vessel class). However, limited entry and more efficient operations (e.g., fewer vessels) at the MSY point would yield an 18 percent profit rate. From the economically efficient viewpoint, this rate is even higher at 70 percent of total earnings while total catch falls almost 13 percent from the MSY level.

Augmented Production

Complicating the supply level is the likelihood of future aquaculture enterprises and the uncertainty of future markets for underutilized species. With the former alternative, high yields—perhaps several hundred times natural levels—of estuarine species can result by concentrating organic matter as a food source into a small water area. However, such yields depend not only on the quantity of organic matter, but also on the ability of the fish or shellfish to strain food from the water. Some methods of aquaculture are known to have an adverse impact on the estuarine environment, however, and may reduce the natural productivity there. This factor must carefully be weighed when calculating the net benefits from such activity.

In addition, the cost of fertilization or artificial feeding may be prohibitive, as a result of the need for large quantities of nitrogen and other essential nutrients. The inclusion of mariculture yields as a benefit of estuarine resources overlooks the issue of manmade versus natural impacts. Since these benefits could be potentially large, they should be distinguished from natural values unless they evolve from a more intensive use of the current nutritional content of estuaries. In Galveston Bay, Tex., for example, it is believed (Stroud, 1970) that additional shellfishing effort could increase current landings by 50 percent, without exceeding the MSY constraint on natural productivity. From an economic viewpoint, however, this increase is justifiable only if marginal costs of fishing are less than added revenues.

Potential returns from aquaculture are particularly striking and can increase fourfold as the intensiveness of the operation increases. Despite these favorable projections, marine aquaculture in this country is oriented mainly toward developmental and pilot studies, whereas inland freshwater "fish farms" are more popular and in many cases are highly productive. It is projected (Commission on Marine Science, 1969) that such fisheries will control a significant share of the consumer market in 20 to 30 years.

Some notable examples of successful mariculture efforts using scientific management schemes have been conducted in the State of Maine (Dow, 1966). Yields approaching $150,000 capitalized value per acre (in 1973 prices) have been recorded for clam beds. While this value is extraordinarily high, it does indicate that certain highly productive subareas of the estuary can yield several times their normal output of fishery products.

Another means of augmenting current supplies is to market underutilized species or byproducts thereof. The potential harvest adjacent to the U.S. coastal zone is enormous and could easily exceed present production by a factor of 10 (Commission on Marine Science, 1969). Whether these can be economically harvested and processed will depend on individual species. The natural supply of these species should be valued as an optional resource benefit for future consumption.

Unfortunately, supply predictions in the future are beset by a number of uncertain economic and political factors. To include the above supply augmentation schemes in the analysis could thus involve so many ill-founded assumptions as to erase any credibility in the estimates. But certainly these options need to be recognized in the analysis, and their likely impacts on potential value should be compared.

Competing Activities

Another factor influencing the supply function for commercial fisheries is interference from other activities that depend either directly or indirectly on estuarine resources. The above survey of pollution damages, for example, shows how industries and municipalities have reduced natural stocks of fish or shellfish. Throughout the United States, commercial and residential land developments have been responsible for an acute loss of estuarine habitat for fish and wildlife. Further, it can be expected that future aquaculture activities in the estuary will have some detrimental effects on the populations of surrounding wild species of fish and wildlife.

A more visible challenge to commercial fishing arises from sport fishing interests. In many regions, the high level of expenditures for recreation, and particularly fishing, indicate social benefits derived from these activities. As a result, commercial fishermen in some cases may be faced with dwindling catches and restricted fishing grounds. The corresponding rise in marginal costs could force commercial fleets to move to more productive areas, to change the species mix of catches, or to curtail production and perhaps eventually go out of business. Fishery benefits thus cannot be calculated in isolation of other estuarine values. Implicit in each estimate, therefore, is an assumption on the extent of competing land and water uses.

Distribution of Catch

In many estuaries the annual harvested value of commercial fish is recorded on a unit acreage basis. Averaging total catch in this manner fails to disclose subareas of greater productivity. Because the harvest is unequally distributed, average values thus give insufficient data on setting priorities for the most valuable portions of the estuary.

Variations of landing revenue by estuarine area can be very significant. In Gloucester Harbor, Mass., (Jerome, 1969), for example, the annual income from shellfish is almost $100 per acre averaged over the entire estuary. Yet if this record were restricted to soft-shell clam habitats, the unit value would increase to $240. An even more striking example is provided by the intensiveness of shellfishing in the mouth of the Delaware River (Shuster, 1971). While the harvest value over the entire water surface area was $13 per acre, production was actually restricted to about one-fourth of this area, yielding a unit revenue of $51. But even this estimate of habitat area may be overstated as commercial harvesting takes place on a small portion of this region. Adjusting for actual fishing grounds raises the unit value to $170. It is further argued that harvest rates may be less than 10 percent of the actual production in this estuary. Hence, catch and population may differ considerably, which further complicates the projection of fishery values in future years.

Regional Impacts

Arising from direct benefits and costs in the commercial fishing industry are secondary income flows throughout the economy—both on a local and a national basis. Tracing these flows requires a detailed and generally complex input-output analysis of household expenditures and economic sector dependencies within local boundaries, and an account of interregional trade volume and government transactions.

Several references from the literature provide insights on these impacts. In the southern New England region (Rorholm, 1967), the commercial fishing industry was partitioned into these components: fish catching, fresh and frozen fish processing, and fish wholesaling and jobbing. Sales and local value added were estimated for each component, as were general income multipliers ranging from 2.96 for catching to 3.74 for frozen fish processing. In Clatsop County, Ore., (Collin, 1973), the local income multiplier for fish catching equals 1.23, whereas it is 1.81 for fish processing. These values are relatively small because of the county's strong dependence on non-local business. For the Texas marine area (Milroy, 1970), the multiplier for the fishery sector is assumed to be 1.75. It is obvious from these few studies that local impacts vary considerably and depend on the size and industrial composition of the economy, and the extent of marine activities in the region.

CONCLUSION

Some of the most valuable fish resources are dependent on estuarine habitats, with approximately two-thirds of the total dockside revenue of U.S. commercial fisheries identified in one way or another with these marine waters. Yet despite this important life-support function, estuaries have lost more than 7 percent of their fish and wildlife habitat to commercial and housing development over the past two decades (Commission on Marine Science, 1969). In many coastal areas these developments proceeded without any comparison of the socio-economic welfare impacts realized by competing uses of the estuarine area. To preserve remaining habitats from land use encroachments, it is thus important that comprehensive values of natural resources be reorganized and assessed to the fullest extent possible.

The object of this paper was to summarize the state-of-the-art on the estimation of commercial fishing benefits associated with U.S. estuaries. Until now, there has been no attempt to critique or even compile empirical studies on a regional basis. This survey reveals that a large number of estimates have been published (see Table 1), contrary to the widely held opinion that few exist Most of these estimates pertain to recorded landings along the New England and the gulf shorelines although several, primarily off the south Atlantic coast, evaluate the potential impacts of increased yield through mariculture techniques

Despite their large number, practically all of these estimates are conceptually invalid since they measure private rather than social welfare gains. In at least one instance (Tuttle, 1974), however, private revenue (based on the exvessel price of fish) was used as a conservative estimate of the net benefits realized at major phases of the fishing industry But using this surrogate value, to avoid inherent difficulties of estimating welfare impacts, not only leaves the degree of underestimation unanswered, but also could be an incorrect assumption for other regions It is therefore misleading and, furthermore, unjustified from the perspective of economic theory, to value estuarine resources solely in terms of market prices

An additional area of economic evaluation is the contribution that estuaries make to U S sport fisheries It is generally agreed that the benefits derived from this important recreational activity, if quantified, would exceed those of the commercial fisheries The obvious implication is that the exclusion of sport fisheries values further underestimates the true worth of the estuary

To close the gap between the conceptual framework and the validity of estimates, more research should be devoted to economic aspects of fisheries The following recommendations pertain more specifically to this goal

- Determine economically optimal net rents at the fish catching phase for a wide variety of estuarine-dependent species
- For various species of fish and shellfish assess net profits at the processing and distribution phases
- Derive consumer demand functions at the retail phase, and estimate consumer surplus given current market prices for a selection of fish products
- Investigate regional differences of the welfare impacts described above
- Estimate the total biological productivity within an estuary This value gives a broader perspective than catch statistics on commercial fisheries, since the harvest of natural products from the end of the food chain represents less than 5 percent of total productivity (Odum, 1975)
- Determine the value of sport fisheries benefits derived from the estuary
- Derive all benefits in a capitalized value context, in addition to their magnitude over the current year
- Obtain regional estimates and supportive data on the potential of increasing natural productivity in estuaries whether by improved fishing efficiency or other means
- In each estuary, perform a zone-oriented analysis whereby the most productive areas are identified. Economic values of these areas versus the mean value over the entire estuary should also be compared.

Information associated with these recommendations could assist coastal zone managers in planning economically optimal uses of estuaries Without such information, the rationale underlying their decisions will remain inadequate By considering benefits in as comprehensive a manner as possible, the policymaker would proceed with a more balanced perspective of the impacts of estuarine uses on societal welfare Only in this manner can there be a reasonable assurance of optimizing the benefits of resource allocation

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CONCLUDING REMARKS

ORGANIZATIONAL ARRANGEMENTS FOR MANAGEMENT OF ATLANTIC COAST ESTUARINE ENVIRONMENTS

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ABSTRACT

Since 1969, the general trend in management of Atlantic coast estuarine environments has been to strengthen state and regional capabilities principally through new federal funding programs Interstate management entities, with limited exceptions, are not playing an extensive or significant role

Many approaches are used for estuarine management by the various states Critical management decisions typically involve specific site-related permit decisions In many states, these individual decisions are made within a framework of overall state guidelines, policy, or legislative mandate All states have adopted water quality standards and all but one have wetlands management programs A few states have adopted strict Coastal Zone Management programs No states have separate estuarine management agencies, relying instead, on several related agencies or centralized environmental "super agencies"

Coordination is the most necessary element of effective estuarine management The Coastal Zone Management Act has provided states with the initiative (and funds) to effect a better coordination within their own agencies and with other states on a regional basis

Estuarine management has improved in the period 1969–1974 as a direct result of increased federal funding supported by a growing awareness of the importance of a quality environment among the general population The principal factor in estuarine management in the next five to 10 years will probably be local acceptance and support of developing Coastal Zone Management programs

INTRODUCTION

Status of Arrangements in 1969

In 1969, the Federal Water Pollution Control Administration, Department of Interior, in its "National Estuarine Pollution Study" summarized the status of estuarine management in the nation's estuaries In respect to federal activities, seven Departments (Interior, Commerce, Transportation, Agriculture, Health, Education and Welfare, Housing and Urban Development, and Defense (U S Army Corps of Engineers)) were identified as having the prime impact on management of the nation's estuaries Table I briefly summarizes the major activities of these departments pertinent to most of the nation's estuaries Activities of other agencies in these departments and other departments, of course, had at that time (and still do) impacts on the nation's estuaries, but these impacts were usually of a more indirect nature or related to site-specific activities, such as the Atomic Energy Commission or the Federal Power Commission licensing of specific power plants

The 1969 role of federal activity in estuarine management was described as one of support and technical assistance to the states, regulatory activities within current law at that time, and direct provision of normal federal services, such as navigation aids, channel and harbor maintenance, protective works, and environmental prediction of tides, currents, and weather "The National Estuarine Pollution Study" urged augmentation of existing federal programs including technical, research, and enforcement programs In addition, development of a national policy, a stronger means of coordinating federal programs, and a system of planning grants to the states were encouraged

As with federal management efforts, the tone of "The National Estuarine Pollution Study" was generally critical of states' role in estuarine management Although a few states were considered to have made significant progress in the area of estuarine management (Massachusetts was singled out as the most advanced state), most were considered to have made little or no progress. The major criticisms leveled at the states in this report were lack of a central organizational/coordinational

Table 1.—Summarization of Federal activities in estuarine areas in 1969.

Department	Major Agencies	Routine Activities
Interior	Bureau of Commercial Fisheries[1] Bureau of Sport Fisheries & Wildlife[2] Bureau of Outdoor Recreation Federal Water Pollution Control Administration[3] Geological Survey National Park Service Office of Water Resources Research Office of Saline Waters	Permit review in conjunction with Corps of Engineers permit activities; Land and Water Conservation Fund Program; Sewage and Construction Grants; Recreation; various planning and management and resource preservation and development granting programs; water flow data and resource compilation and research activity; participation in River Basin Commission studies.
Commerce	Maritime Administration Environmental Science Services Administration	Port development; mapping and charting; environmental prediction (tides and currents); research.
Transportation	Coast Guard	Law enforcement; aids to navigation; rescue; boating safety; port security; control of shipping.
Defense	Corps of Engineers	Maintenance of navigable waters; permit control of dredge and fill operations; permit control of effluent discharge in navigable waters; harbor construction; shoreline protection.
Agriculture	Soil and Conservation Service Forest Service Water Resources Council	Soil and water conservation projects; sewer and water planning and construction grants; watershed protection; flood control.
Health, Education & Welfare	Food and Drug Administration Bureau of Water Hygiene Bureau of Radiological Health Bureau of Solid Waste Management	Marine health; pesticide monitoring; radionuclide monitoring; public water supply; food and drug purity from marine sources; solid waste disposal; shellfish sanitation program; dumping.
Housing and Urban Development		Planning and assistance in water use; area wide and local planning; water and sewer facilities grants; open space land grants; National Flood Insurance Programs.

Source: "National Estuarine Pollution Study," 1969, pp. V-5 through V-39.

[1] Transferred to National Oceanic and Atmospheric Administration, U.S. Department of Commerce by Reorganization Plan 4 of 1970.

[2] Now U.S. Fish and Wildlife Service, U.S. Department of Interior.

[3] Transferred to Environmental Protection Agency by Reorganization Plan 3 of 1970.

focal point and lack of statewide comprehensive estuarine management plans.

The study expressed the viewpoints of states with regard to estuarine management as falling into three categories:

1. State ownership/management of estuarine resources with federal assistance;
2. Federal-state-local partnership for estuarine management; and
3. Autonomous state management.

The great majority (91 percent) of the states' viewpoints fell into the first category. The preferred role of the federal government in estuarine management was in the areas of financial, technical, and research assistance. Recommendations of the study with regard to the state role called for increased state authority in this area with development of proper organizational arrangements within the states to exercise this authority.

Strong criticism was also expressed of the local government level of estuarine management. Lack of adequate staff and funding capabilities to plan, decide, and implement regulations was highlighted. The presence of underutilized management tools such as legislation, public ownership, public education, permits, zoning, planning, and financial inducements (tax incentives), was noted. Although critical of the local role at that time, the study stressed the crucial role that local governments will have to play in effective estuarine management.

The overall assessment of the effectiveness of estuarine management at all levels of government—federal, state, and local—was disappointing. Several recommendations were made of ways of improving estuarine management at all levels. Coordination, planning, and cooperation were stressed as necessary parts of a successful estuarine management program.

Legislative Federal Developments

The major thrust of federal initiatives in the period since the completion of "The National Estuarine Pollution Study" (1969–1973) has been to strengthen state and regional capabilities in the area of estuarine management, and to make the federal bureaucracy responsive to environmental issues. The National Environmental Policy Act (NEPA) of 1969 (Public Law 91-90) which established the Council on Environmental Quality required for the

Table 2 —Components and functions transferred to the Environmental Protection Agency by Reorganization Plan No 3 of 1970

Component/Function	Source
Federal Water Quality Administration	Department of Interior
Pesticide studies	Department of Interior
National Air Pollution Control Administration	Department of Health, Education and Welfare
Bureau of Solid Waste Management	Department of Health, Education and Welfare
Bureau of Water Hygiene	Department of Health, Education and Welfare
Portions of Bureau of Radiological Health	Environmental Control Administration of Department of Health, Education and Welfare
Pesticide functions carried out by Food and Drug Administration	Department of Health, Education and Welfare
Authority to perform studies related to ecological systems	Council on Environmental Quality
Certain radiation criteria and standards functions	Atomic Energy Commission and Federal Radiation Council
Pesticide registration and related activities	Agricultural Research Service, Department of Agriculture

first time in the nation's history the inclusion of environmental considerations in federal decision-making, and the issuing of a detailed statement on the environmental impact of the decision.

Reorganization Plans 3 and 4 of 1970 which established, respectively, the Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) within the Department of Commerce, provided focal points for much of the federal estuarine management efforts In this reorganization, EPA received the components and functions listed in Table 2, and NOAA received the components and functions listed in Table 3 These reorganization plans resulted in primarily three federal agencies or departments having preeminent responsibilities in estuarine management

1 EPA became primarily responsible for pollution monitoring and control;

2 NOAA became primarily responsible for providing technical and scientific assistance in the area of living resources and environmental prediction, and

3 The Corps of Engineers retained their permit authority in navigable waters

The Department of Interior retained a strong advisory role in estuarine management through its authority to comment on Corps of Engineer permit applications, spelled out in a memorandum of understanding, dated July 13, 1967, between the Secretary of Interior and the Secretary of the Army The Department of Transportation retained its strong enforcement role and a major role in oil pollution control (primarily in the area of contingency action) through the Coast Guard

Major federal legislation relating to estuarine pollution control and management during this period included the Federal Water Pollution Control Act Amendments of 1972 (P L. 92-500) The Act presents national goals and guidelines to which the states' programs must adhere, and is considered by many commentators (McMahan, 1972, Rasmussen, 1973, Kuchenbecker and Long, 1973) to be the most effective anti-pollution legislation regarding

Table 3.—Components and functions transferred to the National Oceanic and Atmospheric Administration by Reorganization Plan No. 4 of 1970.

Component/Function	Source
Environmental Science Services Administration	Department of Commerce
Elements of Bureau of Commercial Fisheries	Department of Interior
Marine sport fish program of the Bureau of Sport Fisheries and Wildlife	Department of Interior
Marine Minerals Technology Center	Bureau of Mines, Department of Interior
Office of Sea Grant Programs	National Science Foundation
Elements of U S Lake Survey	Department of Army
National Oceanographic Data Center	Department of Navy
National Oceanographic Instrumentation Center	Department of Navy
National Data Buoy Project	Department of Transportation

waterways Also included is the Coastal Zone Management Act of 1972 (P L 92-583), which for the first time in the nation's history stimulates comprehensive estuarine planning and management by the states, providing federal support

Other acts such as the Ports and Waterways Safety Act of 1972 (P L 92-430), the Federal Environmental Pesticide Control Act of 1972 (P.L 92-516), and the Marine Protection, Research, and Sanctuary Act of 1972 (P.L 92-532) provide vehicles for protection of the nation's estuaries against pollution by maritime traffic, pesticides, and ocean dumping, respectively, and serve to complement the provisions of P L 92-500 and 92-583

The funding or contemplation of funding provided by federal sources has assisted the states in strengthening their estuarine management programs particularly with regard to planning for pollution abatement Unfortunately, state advances in the area of pollution control have been hampered by the executive branch withholding (impounding) $3 billion of the $7 billion authorized in the 1972 water pollution control law The effect of this impoundment is difficult to ascertain precisely Efforts to have the money released appear to have been successful, so other than loss of purchasing power due to galloping inflation, the eventual effect may be only a delay in attaining desired levels of control.

PRESENT (1974) ARRANGEMENTS OF ATLANTIC COASTAL STATES

Fifteen states contain estuarine waters that open to the Atlantic Ocean These are grouped into four federal regional districts (Table 4)

Regional planning and coordination is conducted among several groups of states along the Atlantic coast The most widely acclaimed regional group is the New England River Basin Commission (NERBC) The NERBC has taken an aggressive role in research for regional planning, particularly with respect to estuarine and coastal pollution problems This group coordinates activities, supports research and education Financial support for the NERBC comes from two primary sources The operating budget is provided on a 50-50 basis by the federal government and the seven member states The states' share is apportioned by a state developed and approved formula Federal funds are provided through an appropriation to the Water Resources Council Participation in major studies is supported entirely by federal appropriations Operating budgets for FY 1971–1974 have been $309,000, $341,000, $376,000, and $417,000 respectively Major study funds for FY 1971–1973 amounted to $1 4 million (NERBC Annual Reports 1971, 1972, 1973) NERBC has completed several studies of estuarine areas, the most noticeable being the Long Island Sound Regional Study (NERBC, 1971), which has produced a study plan and interim reports on water quality, ecological factors, and erosion and sedimentation, and a series of reports on Boston Harbor's progress towards achieving water quality goals (NERBC, 1970) and its combined sewer overflows (NERBC, 1971)

Table 4 —Atlantic estuarine states (grouped into Federal Regional Districts).

Estuarine States	Federal Regional Headquarters
Maine New Hampshire Massachusetts Rhode Island Connecticut	I Boston, Mass [1]
New York New Jersey	II New York, N Y [2]
Pennsylvania Delaware Maryland Virginia	III Philadelphia, Pa [3]
North Carolina South Carolina Georgia Florida	IV Atlanta, Ga [4]

[1] Also includes Vermont
[2] Also includes Puerto Rico and the Virgin Islands
[3] Also includes West Virginia
[4] Also includes Kentucky, Tennessee, and West Virginia

Another group, the Coastal Plains Regional Council (CPRC) in the southeastern states has contributed to estuarine management through support of member state research activities and a technical assistance program carried out through the Coastal Plains Center for Marine Development Services Neither the NERBC nor CPRC has management responsibilities

Interstate management groups impacting on estuaries include the Interstate Sanitation Commission, the Delaware River Basin Commission, the Potomac River Fisheries Commission, and the Delaware-New Jersey Fisheries Commission The Interstate Sanitation Commission and the two fisheries commissions, as their names imply, are primarily concerned with pollution and fisheries, respectively, and their regulatory powers are limited to these areas The Delaware River Basin Commission has broad powers on matters related to water conservation, control, use, and management in the Delaware watershed The commission has authority to plan, allocate water resources, set standards, and approve all projects which affect water resources No project which will have a substantial effect on water resources of the Delaware Basin may be undertaken without commission approval. The commission is made up of the governors of Delaware, New Jersey, Pennsylvania, and New York, and the U.S. Secretary of the Interior.

The impact of interstate management entities on estuarine management has not changed significantly since the assessment made in "The National Estuarine Pollution Study" (U.S. Department of Interior, 1969) that these entities had not played an extensive or significant role in overall management of the nation's estuaries. The fisheries commissions, for example, deal with only a portion of the estuarine resources although attempts are made to influence management in other areas such as water pollution control to improve fisheries. The Governor's Task Force on Marine and Coastal Affairs (Delaware, 1972) in fact recommended that the Delaware-New Jersey Fisheries Commission be nullified because of its inability to cope with changing conditions of the resource because of cumbersome provisions for changing regulations. This same task force also pointed out that major problems in the Delaware estuary such as the extreme water pollution between Wilmington and Philadelphia and adverse effects of alterations to the Chesapeake and Delaware Canal were still unsolved despite the regional approach taken by the Delaware River Basin Commission (Delaware, 1972).

Other interstate groupings among the Atlantic states (Table 5) are of an advisory, coordinative, and/or educational nature and influence management of estuaries only through persuasion.

Traditionally, it has been difficult to obtain consent from state legislatures to yield their authority to another body less under their influence such as an interstate compact. It is less difficult for a state legislature to agree to support an interstate planning, advisory, or educational group. The question of a compact for the Chesapeake Bay region is raised periodically. The latest proposal along these lines was made by Senator Mc. C. Mathias of Maryland who suggested the states of Maryland and Virginia consider a Title II Commission for the area (U.S. Congress, 1974). One of the difficulties facing acceptance of this proposal is the degree to which such a commission will appreciably assist in solving the problems in the region. Title II Commissions are only advisory and do interject a third party, the federal government, into the picture. Consideration of the problem of interstate planning and management has become part of overall coastal zone management planning efforts of Maryland and Virginia.

The Chesapeake Bay does present an interesting case study on this matter. The Potomac River Fisheries Commission is a two-state management agency that functions as smoothly as single state fishery management agencies. It would appear that since the two states are the same as would be involved in a joint Chesapeake Bay management agency that little impediment to such an arrangement would exist. Actually, although both states bound Chesapeake Bay and the Potomac estuary, there is a distinct difference. The sharing of the main stem of the bay is sequential rather than contemporaneous as in the case of the Potomac estuary. Each state can relatively easily patrol and control access to the bay waters while this is extremely difficult to do in the Potomac estuary.

With the few exceptions noted above, however, estuarine management is a single state function. Within the different states, many different approaches are used for estuarine management. The various components that make up estuarine management are generally not formally coordinated within a state. Coastal Zone Management Act planning and implementation will continue to play a crucial role in effecting formal coordination of estuarine management as part of overall coastal zone management due to the requirement:

> Section 306 . . . (c) Prior to granting approval of a management program submitted by a coastal state, the secretary (of Commerce) shall find that: . . . (2) The

Table 5.—Interstate groupings of Atlantic Coastal States related to estuarine management

Group	Members	Powers
Interstate Sanitation Commission	Connecticut New Jersey New York	Regulatory; coordination
Interstate Commission on the Potomac River Basin	Maryland Pennsylvania Virginia District of Columbia West Virginia *	Research; coordination; planning; educational
New England Interstate Water Pollution Control Commission	Six New England states and New York	Planning; advisory
Delaware River Basin Commission	Delaware New Jersey New York Pennsylvania	Coordination; planning; regulatory
Atlantic States Marine Fisheries Commission	All 15 Atlantic states	Coordination; advisory
Potomac River Fisheries Commission	Maryland Virginia	Regulatory
Susquehanna River Basin Compact	New York Maryland Pennsylvania	Planning; coordination
Interstate Environment Compact	50 states and 2 territories	Coordination

* Not an estuarine state.

> state has . . . (B) established an effective mechanism for continuing consultation and coordination between the management agency designated pursuant to paragraph (5) of this subsection and with local governments, interstate agencies, regional agencies, and areawide agencies within the coastal zone to assure the full participation of such local governments and agencies in carrying out the purposes of this title. P.L. 92-583

During the period of May through November 1974, all of the Atlantic coastal states received initial planning (Section 305) grants under the Coastal Zone Management Act of 1972 (Table 6). It is too early to expect concrete results in estuarine management as a direct result of these funds. Several states, however, anticipated support under the Coastal Zone Management Act and began coastal zone planning with state funds. Florida, for example, published a state coastal zone atlas (Florida, 1972) in December 1972, which provides in map form a delineation of all coastal areas into preservation (no further modification), conservation (controlled modification), and development (few, if any, state controls) areas.

It must be remembered, however, that some elements of what has come to be considered coastal zone management have been functioning in most states for varying periods. A major task of coastal zone planning and management efforts is the identification and coordination of these elements in support of a recognized, stated goal.

Table 6.—Initial Coastal Zone Management Act of 1972 Planning (Section 305) Grants to Atlantic Coastal States

State	Federal Funding	State Funding	Total
Connecticut	$194,285	$130,339	$324,624
Delaware	194,285	83,334	277,619
Florida	450,000	236,000	686,000
Georgia	188,000	115,400	303,400
Maine	230,000	115,000	345,000
Maryland	280,000	185,765	465,765
Massachusetts	210,000	105,000	315,000
New Hampshire	78,000	39,000	117,000
New Jersey	275,000	137,000	412,000
New York	550,000	275,000	825,000
North Carolina	300,000	200,000	500,000
Pennsylvania	150,000	75,000	225,000
Rhode Island	154,415	77,208	231,623
South Carolina	198,485	100,015	298,500
Virginia	251,044	125,522	376,566

Atlantic Coastal States Organizational Arrangements [1]

CONNECTICUT

Estuarine management in Connecticut is primarily the responsibility of the Department of Environmental Protection. Within the department, parks and recreation, fish and wildlife, forestry, and water and related resources are the responsibility of the Division of Preservation and Conservation; while air and water compliance, solid waste management, and pesticides and radiation control are the responsibility of the Division of Environmental Quality. As in most states, many other departments have direct or indirect inputs into estuarine management. Table 7 indicates some of the various agency responsibilities for estuarine management in Connecticut. Estuarine management is not separated organizationally from the management of other areas in Connecticut. Connecticut has wetlands protective legislation.

DELAWARE

Estuarine management in Delaware is primarily focused in the Department of Natural Resources and Environmental Control. Four divisions within the department: Environmental Control; Fish and Wildlife; Parks, Recreation and Forestry; and Soil and Water Conservation, are the primary estuarine management agencies.

Delaware is unique among the Atlantic states in that it has passed a Coastal Zone Act (58 Del. Laws, C. 175) which bans all heavy industry and port or dock facilities within two miles of the shoreline not in existence at the time of the Act's passage in 1971. A permit system administered by Coastal Zone Industrial Control Board operating within the State Planning Office of the executive department regulates all other manufacturing uses or expansion of existing heavy industrial uses.

FLORIDA

Florida's administrative structure is unique among the 50 states in that administrative powers are shared by the Governor and a six member independently elected cabinet. Agencies dealing with estuarine management report to the Governor and the cabinet, sitting as a body. Coastal zone planning is the responsibility of the Coastal Coordinating Council within the Department of Natural Resources. The council consists of the executive directors of the Department of Natural Resources, trustees of the Internal Improvement Trust Fund, the Department of Pollution Control, and the Secretary of Administration. The Coastal Coordinating Council functions as an advisory body to the Governor and cabinet in the area of coastal zone management.

[1] Information for this state-by-state summary was obtained primarily from Ponder, 1974; U.S. Department of Commerce, 1973, 1974; Lynch, Patton and Smolen, 1974; and the individual Atlantic state applications for Coastal Zone Management planning (Section 305) grants.

Table 7.—Some organizational responsibilities for estuarine management in Connecticut.

Responsibilities	Department				
	Environmental Protection	Health	Transportation	Community Affairs	Commerce
Industrial Development	* R	R	R	R, F	* F, P
Water Quality	* R, F, Rev, P	* R, Rev	P		
Erosion	* R, F, Rev, P	* P			
Coastal Recreation	* F, P	* R	Rev, P	P	* P
Wetlands & Critical Area Preservation	* R, P	* R			* P
Subaqueous Mineral Extraction	* R, P		P		P
Energy	R, F, Rev	Rev	F, Rev, P		P

* Agency directly addresses issue.
R, Regulatory authority.
F, Funding authority.
Rev, Review authority.
P, Planning and promotional authority.

Florida maintains permit and/or base control over most estuarine water or margin uses administered by the Department of Natural Resources or the board of trustees of the Internal Development Trust Fund.

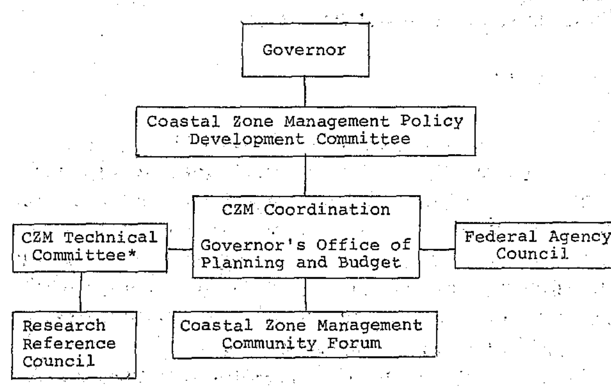
GEORGIA

Estuarine management in Georgia is primarily the responsibility of the Department of Natural Resources. Within this department, the Game and Fish Division is responsible for coastal marshland protection and coastal fisheries management while the Environmental Protection Division is responsible for the water quality standards, water use classification, and the shellfish sanitation programs.

Estuarine planning is the responsibility of a Coastal Zone Management Policy Development Committee which reports to the Governor. The organization for coastal zone management planning in Georgia is shown in Figure 1.

MAINE

Five departments share significant responsibility for estuarine management in Maine. Pollution control is primarily focused in the Department of Environmental Protection which is responsible for licensing of waste discharges and structures in tidal waters or subtidal lands; administration of Maine's Coastal Conveyance of Petroleum Act (including licensing of oil terminals); and enforcement of laws relating to water discharge licenses, air emissions, waste dumping, and water quality laws. The Department of Marine Resources is responsible for fishery law, regulation, and research; maintaining grant, lease, license, and permit records; and monitoring shellfish waters. The Department of Conservation maintains navigational marking and clearances; administers the "Keep Maine Scenic" Law; manages submerged lands; maintains the Coastal Island Registry; and is responsible for watercraft registration and safety. The Department of Transportation houses the Main Port Authority. Monitoring safety of coastal waters for water contact sports and licensing of individual home sewage disposal facilities are the responsibility of the Department of Health and Welfare.



* The CZM Technical Committee consists of:
Department of Community Development
Forestry Commission
Department of Human Resources
Office of Planning and Budget
Georgia Ports Authority
Board of Regents, University System of Georgia
Soil and Water Conservation Commission
Department of Transportation
Coastal Area Planning and Development Commission

FIGURE 1.—Coastal Zone Management (CZM) Planning Organization in Georgia.

MARYLAND

Estuarine management in Maryland is focused in the Department of Natural Resources (DNR) and the Department of Health and Mental Hygiene (H&MH). Other departments such as Transportation (port administration), State Planning (land use planning and state development plan), Agriculture (soil conservation and pesticide control), and Economic and Community Development (waterfront renewal) also contribute to estuarine management.

Estuarine pollution management is exercised by three agencies: the Maryland Environmental Service and the Water Resources Administration in DNR and the Environmental Health Administration in H&MH. The Environmental Health Administration is responsible for water quality and shellfish standards, sewage treatment plant operations, and the statewide health policy. The Water Resources Administration administers the discharge permit system for point sources and is responsible for water quality standards for ground and surface waters. The Maryland Environmental Service is responsible for providing regional and river basin plans for waste water, solid waste, and water supply management.

Most other major estuarine management facets such as wetlands management, shore erosion control, oil terminal licensing, power plant siting, waterway improvement programs, marine policy, fish and wildlife administration, recreation, and coastal zone management are the responsibility of DNR.

A major feature of Maryland's estuarine management program is the Power Plant Siting Act (Anno. Code of Md. Article 96A, Section 23–25) administered by DNR which levees a surtax on electric energy generation in the state to be used for purposes related to power plant operations, particularly ecological baseline studies, monitoring existing operations, long range planning, and acquisition of sites for future power plants.

MASSACHUSETTS

Massachusetts, which was cited by the 1969 "National Estuarine Pollution Study" as having the most advanced estuarine management program, has had a major reorganization of state government. An Office of Environmental Affairs has brought together a number of related agencies. Of particular concern to estuarine management is the Department of Natural Resources (DNR) which has the major responsibility for estuarine management. The responsibilities of Massachusetts agencies with regard to several estuarine management activities are shown in Figure 2.

Overall responsibility for coastal zone management in Massachusetts is housed in the Executive Office of Environmental Affairs.

NEW HAMPSHIRE

New Hampshire's estuarine management programs are not focused in any particular agency or department. Major water supply and water quality programs are administered by the Water Supply and Pollution Control Commission. Coastal zone planning has been assigned to the office of Comprehensive Planning.

NEW JERSEY

All environmental protection in New Jersey is administered by the Department of Environmental Protection (DEP). The Division of Marine Services within the DEP is responsible for coastal zone management, wetlands and shore protection. New Jersey has a Coastal Area Facility Review Act passed in 1973 which divides the coastal areas into various sections, with each section designated for particular purposes. Management divisions affecting estuaries within these designated areas must be compatible with these purposes.

NEW YORK

New York has recently consolidated its environmentally related legislation into one act, the environmental Conservation Law. A marine coastal district has been established which includes all tidal estuarine waters as far up the Hudson as the Tappan Zee Bridge.

The Department of Environmental Conservation is responsible for environmentally oriented estuarine management programs, including coordination of regional and local plans.

NORTH CAROLINA

North Carolina estuarine management and planning agencies are primarily within the Department of Administration and the Department of Natural and Economic Resources.

An Office of Marine Affairs in the Department of Administration established in 1973 has the responsibility of coordination and serving as a communication link with various marine-related programs in North Carolina. A Coastal Resources Commission was legislatively created in 1974 to establish policy,

NAVIGATION

	Public Access Board (DNR)	Div. of Waterways (DPW)	Div. Conservation Services (DNR)	Mass. Port Authority	Div. Marine Fisheries (DNR)
Planning	•				
Setting Standards		•			
Developing Regulations		•			
Enforcement		•			
Monitoring					
Field Studies	•				
Research					
Technical Assistance			•		•
Information Dissemination					
Data Management					
Manpower Training					
Project Management		•		•	
Intergovernmental Coordination	•			•	
Project Review		•			

FISH & WILDLIFE PROTECTION WATER-RELATED RECREATION

	Div. Conservation Services (DNR)	Div. Acquisition & Construction (DNR)	Div. Waterways (DPW)	Div. Fisheries & Game (DNR)	Div. Forests & Parks (DNR)	Div. Marine Fisheries (DNR)	Div. Environmental Health (DPH)	State Geologist (DPW)	Div. Marine & Recreational Vehicles (DMVR)	Div. Water Resources (DNR)	Water Division (MDC)	Parks Division (MDC)	Div. Law Enforcement (DNR)	Public Access Board (DNR)
Planning	•				•					•	•	•		•
Setting Standards	•			•	•	•	•				•	•		
Developing Regulations				•	•	•	•	•	•		•	•		
Enforcement									•		•	•	•	
Monitoring				•		•	•							•
Field Studies				•	•	•	•	•						•
Research				•	•	•		•						
Technical Assistance	•	•	•	•	•	•	•	•						
Information Dissemination	•			•	•	•								•
Data Management	•			•	•	•			•	•				
Manpower Training	•			•	•	•				•			•	
Project Management			•	•	•	•					•	•	•	•
Intergovernmental Coordination	•	•	•	•	•	•		•	•	•	•		•	•
Project Review	•	•			•	•				•	•			

POLLUTION CONTROL

	Div. Water Pollution Control (DNR)	Div. Law Enforcement (DNR)	Div. Marine Fisheries (DNR)	Div. Mineral Resources (DNR)	Div. Fisheries & Game (DNR)	Div. Environmental Health (DPH)	Sewage Division (MDC)	Div. Forests & Parks (DNR)	Div. Conservation Services (DNR)	Mass. Port Authority	State Geologist (DPW)
Planning	•						•			•	
Setting Standards	•					•					•
Developing Regulations	•					•					
Enforcement	•	•					•			•	
Monitoring	•		•	•	•					•	
Field Studies	•							•		•	•
Research	•		•			•				•	•
Technical Assistance	•		•	•		•		•	•		•
Information Dissemination	•					•	•				
Data Management	•										
Manpower Training	•										
Project Management	•						•			•	
Intergovernmental Coordination	•		•		•	•	•			•	•
Project Review	•					•	•		•		•

ELECTRIC POWER GENERATION

	Div. Water Pollution Control (DNR)	Div. Environmental Health (DPH)	Div. Marine Fisheries (DNR)	Div. Water Resources (DNR)	Div. Conservation Services (DNR)	Div. Fisheries and Game (DNR)	Rate Division (DPU)	Dept. Natural Resources
Planning				•				•
Setting Standards	•	•	•	•			•	
Developing Regulations	•						•	
Enforcement	•						•	
Monitoring		•						
Field Studies				•		•		
Research								
Technical Assistance	•	•	•	•	•	•		
Information Dissemination								
Data Management								
Manpower Training								
Project Management								
Intergovernmental Coordination	•	•		•		•		
Project Review	•		•	•				•

FIGURE 2.—Estuarine management responsibilities of Massachusetts state agencies (adapted from the Commonwealth of Massachusetts' Coastal Zone Management Planning grant to the U.S. Department of Commerce).

develop regulations, and adjudicate coastal area permit applications.

The Division of Health Services in the Department of Human Resources administers the state shellfish sanitation program.

PENNSYLVANIA

Pennsylvania's only estuarine area connected to the Atlantic Ocean is a short section of the Schuylkill River below Philadelphia. The Department of Environmental Resources is responsible for the development of the state water plan, management of the state's land and water programs, and all aspects of environmental control.

RHODE ISLAND

In Rhode Island, management of estuaries is centered in a Coastal Resources Management Council which reports directly to the Governor. This council is composed of the directors of the Department of Health along with representatives of the state legislature and the general public. The Division of Coastal Resources of the Department of Natural Resources provides administrative support to the council. The State Department of Health establishes water quality standards.

SOUTH CAROLINA

The Wildlife and Marine Resources Department and the Department of Health and Environmental Control share the major management role with regard to South Carolina's estuaries. The Department of Health and Environmental Control is responsible for management of water pollution, sewage disposal, shellfish sanitation, water supply, and solid waste disposal. The Wildlife and Marine Resources Department is responsible for fisheries resources, dredge and fill operations, and coastal wetlands. As with many other states, many other agencies

	Economic Development				Resource Utilization					Intrastructure						Pollution				Natural Environment					Environmental Hazard		
	Port Development	Industrial Development	Resort-Tourism	Residential Development	Agriculture	Forestry	Commercial Fishing	Recreation	Mineral Extraction	Transportation	Water Supply	Sewage Disposal	Solid Waste	Utilities	Power Plant Siting	Water	Erosion Sedimentation	Dredge & Fill	Spoils Deposition	Coastal Wetlands	Beaches/Dunes	Wildlife Habitats	Unique Ecosystems	Scenic Areas	Flood Zones	Hurricane Impact Zones	Shoreline Development
Division of Administration		P								P	P	P				P			P								
State Development Board	P	PT			T				T	P		T			P				D								
State Highway Department										PM DR							D	D			D						
Land Resources Conservation Comm.				T	P T	P T			PM R		PM R						PM T								P T		
Wildlife & Marine Resources Dept.			T	T		T	PM TR	PM R								P		T R	TR	PM DT R	PT	PMD TR	PM				P
Water Resources Commission				T			P				PM R	P M				P	PM		P	PT R	P	P	P	P	P	P	P
Parks, Recreation, and Tourism			PM DT					PM R																			
Commission of Forestry						PM RT																					
Dept. of Health & Environmental Control		R	R	R			R				R	R	MR		R	PM TR				PR	R						PR
State Ports Authority	PM DR									PM DR																	
Public Service Commission				R						R	R	R		PM R	PM R												

FIGURE 3.—South Carolina: state involvement in estuarine management. P, planning; T, technical assistance; M, management; D, direct development; R, regulation.

contribute to estuarine management. Figure 3 indicates the contribution of South Carolina agencies to estuarine management.

VIRGINIA

Thirty-seven entities have been identified which play a role in state or regional level estuarine management (Laird, 1974). Some have only minor roles, and some occur within the same department under a unified administrative head. These entities have been broken down into six categories as shown in Table 8.

Principal management responsibility rests at present with the Virginia Marine Resources Commission which manages the state's marine and estuarine fisheries. The commission has review authority over wetlands permits, and initial authority over subaqueous permits or leasing for activities affecting estuarine bottoms, including oyster leases, dredging, and subaqueous mining. The State Water Control Board is responsible for water quality and water quality management. The Department of Health also has permit authority in the field of marina sanitation and through its Bureau of Shellfish Sanitation administers the state shellfish sanitation program.

Virginia's wetland management laws (Title 62.1, Ch. 13, Code of Va.) are strongly oriented towards local management. If localities choose (and most have so chosen), initial permit approval of permitted activities is the responsibility of a local wetlands board. The Marine Resources Commission serves as an administrative board of appeals for challenges to local decisions.

The Marine Resources Commission and the State Water Control Board are bodies made up primarily of informed, knowledgeable citizens not otherwise connected to state government. A commissioner of marine resources is appointed to serve at the pleasure of the Governor and serves as chairman of the Marine Resources Commission and its chief executive officer. The other members of the Marine Resources Commission are appointed by the Governor for fixed terms. The State Water Control Board is administered by an executive director. Permit disposition authority rests in these boards, and all decisions related to permit activities must be made in meetings open to the public.

Table 8.—Entities of state government with planning, management, or scientific and engineering responsibilities in estuarine management in Virginia (after Laird 1974)

I. Departments with Overview Responsibility Office of the Governor Council on the Environment Office of the Attorney General II. State Agencies Concerned Primarily with Estuarine and Coastal Areas and Adjacent Marine Areas Marine Resources Commission Virginia Institute of Marine Science Department of Health Bureau of Shellfish Sanitation Virginia Port Authority III. State Agencies Which Have Responsibilities in the Coastal Zone Which Directly Affect Estuarine Management State Water Control Board Commission of Game and Inland Fisheries Department of Conservation and Economic Development Division of Parks Commission of Outdoor Recreation Division of Industrial Development Virginia Soil and Water Conservation Commission Division of State Planning and Community Affairs Virginia Department of Highways Department of Agriculture and Commerce Department of Health Division of Engineering Bureau of Sanitary Engineering Bureau of Solid Waste and Vector Control Bureau of Industrial Hygiene Division of Local Health Services State Corporation Commission	IV. State Agencies Which Have Responsibilities in the Coastal Zone Which Indirectly Affect Estuarine Management Department of Conservation and Economic Development Division of Forestry Division of Mineral Resources Division of Mined Land Reclamation Virginia State Travel Service Historic Landmarks Commission Virginia Outdoors Foundation State Air Pollution Control Board V. Intrastate Agencies Authorized by the Code of Virginia but Which Are Supported by Local Funds and Have an Impact on Estuarine Management Hampton Roads Sanitation District Commission Northern Virginia Regional Park Authority Virginia Beach Erosion Commission VI. Interstate Agencies Relevant to Estuarine Management to Which Virginia is a Party Potomac River Fisheries Commission Atlantic States Marine Fisheries Commission Interstate Commission on the Potomac River Basin

Virginia is unique among the Atlantic coastal states for having an estuarine and marine state research laboratory, the Virginia Institute of Marine Science, which is a separate state agency coequal with the management agencies within the state apparatus. In most states, the estuarine research programs are usually subordinate arms of the management agencies or conducted through formal or informal arrangements with the state university system. The Virginia Institute of Marine Science, however, is independently chartered by the Code of Virginia (Title 28.1, Chapter 9). With an independent charter and separate legislative mandate, the Virginia Institute of Marine Science is able to influence estuarine management practices independent of direct pressures from management agencies.

Coastal zone coordination in the Commonwealth of Virginia is the responsibility of the Coastal Zone Advisory Committee, co-chaired by the Department of State Planning and Community Affairs and the Institute of Marine Science. Other agencies making up the advisory committee are the Division of Industrial Development, the Commission of Outdoor Recreation, the Marine Resources Commission, the State Water Control Board, the Commission of Game and Inland Fisheries, and the Department of Conservation and Economic Development. State level coordination between state agencies is being focused in a developing secretariat which reports directly to the Governor. At present, each state agency reports to a secretary. The majority of agencies which have a major role in estuarine management report to the Secretary of Commerce and Resources.

SUMMARY

As can be seen by this brief review of state programs, many approaches are used for estuarine management among the various states. The critical management decisions which impact the estuarine areas usually involve specific site-related permit decisions. In many states, these individual decisions are made within the framework of overall state guidelines, policy, or legislative mandate.

All but one of the Atlantic states (South Carolina) have adopted specific wetland management programs; all have adopted water quality standards; and some (Delaware and New Jersey, in particular) have adopted strict coastal area zoning programs.

Table 9.—Summary of estuarine related State Land Acquisition Authority

State	Agency	Purpose	Authority
Connecticut	Dept. of Environmental Protection	Wetland Acquisition General Purposes	C.G.S.A. 26-17a C.G.S.A. 22a-25
Delaware	Dept. of Natural Resources & Environmental Control	Parks	D.C. 7-5802
Florida	Water Management Districts	Wetland & Water Management	F.S. 373-139
Georgia	State Forestry Commission	Forests	G.S. 43-207
Maine	Board of Environmental Protection Commission of Sea and Shore Fisheries	Wetlands Acquisition Flats & Waters for Scientific Purposes	M.R.S.A. 12-4701 M.R.S.A. 12-3701
Maryland	Dept. of Natural Resources	General Purposes	M.C.A. 66C-186
Massachusetts	Dept. of Natural Resources	Coastal Wetlands Wildlife Sanctuaries State Parks & Forests	M.G.L.A. 130-105 M.G.L.A. 131-7 M.G.L.A. 132A-2A
New Hampshire	Dept of Fish & Game	Coastal Wetlands	N.H.R.S. 483-A:1
New Jersey	Commissioner of Conservation & Economic Development	Wetland Acquisition	N.J.S. 13:8A:4 & N.J.S. 13:8A-24
	Hackensack Meadowland Development Commission	Wildlife Habitats Wetland Development	N.J.S. 13:1B-15-5 N.J.S. 13:17-6(g)
New York	Dept. of Environmental Conservation	Wetlands & Forest Preservation Fish & Wildlife Management	L.N.Y. ECL §260 L.N.Y. ECL §10501
North Carolina	Dept. of Conservation and Development	Natural & Scenic River Areas and Estuarine Areas	S.N.C. 113A-34
Rhode Island	Dept. of Natural Resources	Wetlands Acquisition	R.I.G.L.A. §2-1-15
South Carolina	No Programs		
Virginia	Cities, Counties, Towns Various State Agencies Virginia Outdoors Foundation Commission of Outdoor Recreation	Federal Water Resource Development Projects Open Space Lands Open Space Lands Scenic Rivers Areas	Va. Code 62.1-150 Va. Code 10-152 Va. Code 10-163 Va. Code 10-175

No states have organized separate estuarine management agencies which exercise all management functions. Within most states, estuarine management is the function of agencies which exercise related management functions on a statewide basis. Some states have centralized environmental management into a single "super" department. In these departments, there are often separate divisions which deal with marine resources, but estuarine water quality management functions are usually the responsibility of a division or agency with statewide authority.

At the opposite end of the spectrum from the "super" department exercise of estuarine management is the private "citizen board" concept of management decisionmaking used in Virginia at both state and local levels.

State overview in Rhode Island is by a board made up of ex officio agency heads, state legislative representatives, and private citizens, while in Florida this authority is held jointly by seven elected officials, the Governor and the independently elected cabinet. In addition to permit systems, another tool available to estuarine managers is land acquisition. All Atlantic coastal states have some type of land acquisition authority relevant to estuarine management. These are listed in Table 9.

It is apparent from the multiplicity of agencies with managerial responsibilities that coordination is a necessary element to effective estuarine management. Coordination of environmental regulatory activities has been achieved in several states by centralization of agencies into a super agency. This still, however, leaves the problem of activities which have a measurable impact on estuaries but which are not directly regulated by environmentally oriented agencies.

The Coastal Zone Management Act has provided the initiative to states to effect better coordination of those activities important to sound estuarine management. Although not devoted solely to estuarine management, coastal zone management encompasses all aspects of estuarine management. Improvement in this coordination should be apparent in the very near future.

As mentioned earlier, all Atlantic coastal states are participating in the planning phase of the Coastal Zone Management Act. All states received planning grants during 1974. Because of the recency of these planning grants, there has been insufficient time to produce specific accomplishments.

State preparations anticipating funding of the CZMA have, however, resulted in formation of either legislatively or executively mandated interagency committees, commissions, councils, or task forces in most states. The CZMA guidelines strongly encourage management at the lowest possible level of management, primarily localities, within, however, state and federally agreed upon principles. The great advantage to the states in developing and adopting an approved CZM program is that once approved by the Secretary of Commerce, the state plan also becomes the guideline for and is binding upon federal programs operating in state coastal areas.

The success of estuarine management programs in future years probably depends upon the success of developing the state-local coordination and cooperation necessary to implement developing coastal zone management plans.

Experience in various states differs as to the effectiveness of local control over environmental matters. In Virginia, local management of wetlands is considered to be successful to date (the Virginia Wetlands Law became effective July 1, 1972), and is being studied as a possible model for coastal zone management within the state.

Estuarine management, particularly as exercised through permit programs, receives much criticism from both environmentalists and developers. The major criticism of both sides is the multiplicity of permits required for a single authorization to proceed with a proposed project. Frequently advocated by both groups are "one stop" permit systems, each side of course assuming "one stop" systems will favor its position. Until a different system is devised which will adequately assess an activity's impact on the various facets of estuarine management, however, a "one stop" system will probably not serve the best interest of the citizens of a state taken as a whole and divorced from particular advocacy roles in a given controversy.

It is unlikely that agencies will be created within the states' organizational frameworks which will function solely or primarily as the manager of a state's estuarine areas. What can be expected is an increasing awareness of the need for closer coordination and cooperation between agencies serving planning, management, and advisory roles in estuarine areas. This need has already been recognized by most states and several have begun to effect this coordination. The next several years will see marked improvement in this area, although there will be difficulties in reconciling federal, state, and local goals, responsibility, and authority. These difficulties, with application of the emery powder of federal funding, will be smoothed sufficiently so that more effective management of estuarine systems will be developed.

Estuarine management has improved in the period 1969–1974. Much of this improvement is the direct result of increased federal funding supported by the general awareness of the importance of a quality environment in the average citizen. Care must be exercised, however, that "ecological fervor," unaccompanied by a sound educational program, does not create an environmental backlash. The reverse is also true, however, that care must be exercised to ensure that temporary crises (of long or short duration) such as the energy squeeze of the early and mid-1970's, are not used as an excuse to dismantle the sorely needed apparatus for environmental concern that has been and is being constructed. It has become apparent to taxpayers that a quality environment is expensive. Without well-documented, understandable evidence that suggested pollution control methods are necessary, public support will not be available and environmental quality will not be maintained or improved.

The Coastal Zone Management Act of 1972 recognizes many of these problems and the regulations implementing the program emphasize the need for developing citizen awareness, participation, and support.

A critical factor in future estuarine management will be the roles of federal, state, and local management agencies. Unfortunately, there is little data available from which to deduce the exact mix of responsibilities which will ensure success. The general approach of the Coastal Zone Management Act—that of a state program developed under federal guidelines which, when federally approved, provides the criteria for federal actions in the region—is readily acceptable at the state level. Still to be determined is the acceptance of possible state constraints on certain federal agencies and even more important, the acceptance by localities of the state plan.

The principal factor in estuarine management improvement in the next five to 10 years will be local acceptance and support of coastal zone management.

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EVALUATION OF WATER QUALITY IN ESTUARIES AND COASTAL WATERS

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ABSTRACT

Estuaries and coastal waters, comprising less than 5 percent of earth's surface, are under ever-increasing pressures from growing populations and demands. Yet these complex and dynamic waters are the key to preserving the viability and productivity of the oceans. Maintenance of their quality is vital to man and his future, causing much concern, especially in the United States. Consequently, considerable research, legislation, and other efforts oriented at improving management of estuarine and coastal waters have gone forward in the last 10 to 15 years. These are discussed in this chapter.

Despite all these efforts, the condition of estuarine environments and resources continues to decline. Several factors appear to be causal. The "state of the art" for control of quality in estuarine and coastal waters must be rapidly improved to reverse the downward trend. Recommendations are made.

As these improvements are accomplished, we will slow and eventually stop, even reverse, the degradation of these vital waters. While making control procedures more accurate and precise, we must also reduce the economic and social costs of controls without lessening their effectiveness.

INTRODUCTION

Historical

Humans and human activities have long been concentrated on the shores of the seas, or along the tributaries which empty into those seas. Given this shoreward distribution of a rapidly multiplying people and their burgeoning societal activities, it is small wonder that we are now greatly disturbed over the worsening condition of the coastal waters and tidal tributaries fringing the oceans of earth.

Concern with quality of the environment focused early on its decline in natural waters. Recognition of atmospheric problems such as contamination of air by heat or chemicals and the possibility of unintentional weather modification, developed later. Probably because they are more easily damaged and more readily observed, upland brooks, small rivers (running waters), and ponds and confined lakes (still waters) called for and received attention first. Later, the larger upland rivers and the Great Lakes began to show regular fish kills and other signs of degradation. Thus, much of the early effort at pollution abatement by science and technology, government and industry was devoted to these essentially upland waters. Only in recent decades have the great tidal tributaries, with their massive fresh and saline reaches, and the coastal waters of the world's seas and the vast oceans, themselves, been attended. The sights and smells of pollution, long apparent in natural inland waters, appeared in most estuarine and oceanic waters very late. Awareness that the oceans and seas of earth are not as remote or inviolate as formerly believed has been slow in coming compared with man's ability to use, to exploit, and to pollute.

It is now clear that control of the condition of oceanic waters will depend primarily upon achieving reasonable control over estuaries and other coastal waters. Additionally, control of coastal waters is necessary in and of itself because it is these waters which most affect man and it is important to maintain an adequate environment for human society.

Belated though awareness of estuarine and coastal waters may have been, much attention has been given them since the 1960's when the strong concern manifesting itself today surfaced and the Water Quality Act of 1965 (PL 89-234), the Clean Water Restoration Act of 1965 (PL 89-753), and the National Environmental Protection Act of 1969 (PL 91-190) came into being.

Legislation aside, concern has also been apparent in the growing number of publications relating to environment, its relation to man, and to the worsening status of many environments and resources. Many governmental groups have been commissioned to consider these problems at all levels—local, regional, state, interstate, federal, and even international. Reports have been written, new legislation passed, and organizations established and modified. Unfortunately, reorganization has occurred so many times as to make some agencies unstable and render it difficult for them to accomplish their objectives. For example, because of its changing and confusing organizational milieu, progress and improvement of the Environmental Protection Agency (EPA) has been slowed.

A large number of major studies of the nation's estuarine systems and of individual estuaries have been conducted since 1960 along with a host of lesser, but useful smaller works. See, for example, (Lauff, 1967), (USDI, 1969), (USDI, 1970), (Stroud, 1971), (Chabreck, 1973), (Clark, 1974), (Odum et al., 1974) and many others.

Manifestation of Interest by Legislative Action

Among the landmark federal enactments which have resulted from this growing awareness and concern for tidal waters have been:

1. *The Water Quality Act of 1965* (PL 89-234) which among other things, initiated the National Water Quality Standards Program [Sec. 10 (c)].

2. *The Clean Water Restoration Act* of 1966 (PL 89-753), which focused on problems of maintaining and restoring quality and uses of the Nation's surface waters. Additionally, in that act the Secretary of the Interior was directed [Section 5 (g)] to study nationwide problems of estuarine pollution. The resultant 3-year effort yielded a very interesting report submitted to Congress in November 1969.

This three volume report was entitled, "The National Estuarine Pollution Study" (USDI, 1969). Noteworthy among its recommendations was development of a comprehensive national coastal zone management system. (This recommendation, seconded by many other study groups, has been acted upon partially by enactment of PL 92-583, The National Coastal Zone Management Act of 1972).

3. *The Marine Resources, Engineering and Development Act* of 1966 (PL 89-454), which focused attention on marine waters and their resources, environments, and uses by society. It also directed: a) evaluation of and improvement in the federal efforts in ocean affairs, and b) a comprehensive review of all ocean-oriented matters. This review was designed to lead to development of a comprehensive national effort to better control, utilize, and preserve the resources and environments of marine waters.

The first responsibility was given to the National Council on Marine Resource and Engineering Development (NCMRED—also known as The Marine Science Council), a federal body consisting of the several departmental Secretaries, the Director of the National Science Foundation, the Chairman of the Atomic Energy Commission and chaired by the Vice President. Dr. Edward Wenk, Jr. was its first executive secretary. A series of annual reports was issued by the Council under the general title, "Marine Science Affairs," with appropriate dates and subtitles (cf. References). One of its four interagency committees, the Committee on Multiple Use of the Coastal Zone, helped focus attention on the fragile area called the coastal zone in various publications and reports and in doing so, joined others in contributing to that developing national program.

The task of conducting a comprehensive nationwide review of all ocean-oriented matters (the last charge mentioned above) fell to the civilian-composed Commission on Marine Science and Engineering Resources (COMSER—sometimes called the Stratton Commission after Dr. Julius A. Stratton, its chairman). This commission expired at the end of a fruitful 3-year life that resulted in a series of comprehensive reports. The summary volume of the four volume set entitled, "Our Nation and the Sea," is an effective distillation of the entire national marine effort to that point.

The commission found great need for considerable attention to the pressured and deteriorating coastal zone and its recommendations for correction form one of the strongest foundations for the current emphasis on the margins of the sea. With those groups mentioned above, the commission contributed significantly to the Coastal Zone Management Act.

4. *The Estuary Protection Act* (PL90-954) reiterated Congress' awareness of the critical nature of coastal waters and directed the Secretary of the Interior "to conduct an inventory and study of the Nation's estuaries and their natural resources" in cooperation with the states.

This study, authorized in August 1968, and funded initially in July 1969 was completed and resulted in a report entitled, "National Estuary Study." Its seven volumes were transmitted to Congress in January 1970 (USDI, 1970). They, too, concluded that the estuarine zone of the United States is a critical environmental and resource area and recommended stronger efforts to manage it wisely, focusing the management responsibility and capability in the states.

5. *The Federal Water Pollution Control Act Amendments* of 1972 provided for establishment, publica-

tion, and, where necessary, revision of comprehensive water quality criteria, among other provisions. Accomplishments and offshoots of this legislation are discussed in greater detail below.

Special Studies and Reports

While these legislative efforts came into being and the activities they called for were pursued to fruition, the Federal Water Pollution Control Administration (FWPCA—now EPA) of the Department of the Interior has established the National Technical Advisory Committee on Water Quality Criteria (NTAC). The body, which was advisory to the Secretary of the Interior, was developed in response to Paragraph 3, Section 10 of the Federal Water Pollution Control Act as amended by the Water Quality Act of 1965. The Committee, named in early 1967, worked vigorously throughout the year and submitted its report to the Secretary in April 1968.

The work dealt extensively with problems of maintaining the maximum utility and quality of estuarine and coastal waters and presented a large number of water quality criteria recommended for use in the management of those waters. These criteria were supposed to form the basis for new water quality control standards, and they did! Both the criteria and standards have been in widespread use since.

In 1971 the Environmental Protection Agency, anticipating the Amendments of 1972 to the Federal Water Pollution Control Act, commissioned another examination of the status of knowledge of surface and ground waters and the elements related to quality. Under a contract to the National Academy of Sciences-National Academy of Engineering (NAS-NAE), several subcommittees comprising the overall Committee on Water Quality Criteria of the Environmental Studies Board of the National Research Council (NRC) were established to review and, if necessary, revise the water quality criteria previously developed. Its report entitled "Water Quality Criteria 1972" was completed in 1972 but not made widely available until recently, (NAS-NAE, 1973)[1].

As indicated above, the NAS-NAE effort was undertaken as a contractual obligation to EPA. Whether the different status of the NAS-NAE appointment group, as contrasted with the old NTAC, which was an official advisory committee reporting to the Secretary of Interior, will have an effect on the ultimate development of revised standards from these criteria, will be interesting to see. It is too early to tell. As will be shown below, EPA has responded by utilizing a large number of these criteria directly in developing their own proposed criteria (U.S. Environmental Protection Agency, 1973).

[1] Though the title indicates that the report was completed in 1972 internal evidence in the "Blue Book" indicates that it was not actually printed for circulation until early 1973. It was not widely available until then.

Other Activities

There have been a number of other significant activities relating to problems of coastal and estuarine environments which impinge upon assessment of the status of those waters and of the seas and oceans into which they empty. Among them have been the various pollution-related research efforts of the National Science Foundation through its projects administered by the International Decade of Ocean Exploration Program. Several useful publications have resulted. See, for example, Goldberg (1972b), and Duce, Parker, and Giam (1974). Too, NSF's Research Applied to National Needs Program (RANN) has contributed significantly by supporting water quality-related activities in various estuarine and coastal areas. RANN has also sponsored several review activities such as workshops and symposiums devoted to problems of coastal waters and lands. As examples see: "The Water's Edge: Critical Problems of the Coastal Zone," (B. H. Ketchum, ed., 1972) and "The Chesapeake Bay: Report of a Research Planning Study," (Beers, et al, 1971).

The massive report in four volumes prepared for FWPCA as part of the National Estuarine Pollution Study of 1968 and 1969 and published by the Conservation Foundation under the general title, "Coastal Ecological Systems of the United States" (Odum, Copeland and McMahan, eds., 1974), is worthy of special note here as are the 1971 reports of the NAS-NRC Ocean Affairs Board, "Marine Environmental Quality," and NAS-NAE Committees on Oceanography and Ocean Engineering (NASCO and NAECOE) "Waste Management Concepts for the Coastal Zone," (NAS-NRC, 1970).

All of these activities have served to focus attention on the nation's coastal and estuarine waters and on the need to understand and manage these waters effectively so that they will be of maximum utility to society and will be available in undiminished quality and quantity to posterity. They have also served to establish a stronger basis for developing management efforts and to indicate where current knowledge and managerial ability are weak.

Purposes

Some aspects of the legislative and technical history of the effort to manage the quality of estuaries and coastal waters have been presented above. Important as it is to understand these historical aspects, the overall purpose of this chapter is a general evaluation of water quality in the nation's estuaries as a whole. In doing so, we seek to examine the current status of the national estuarine system. This will be done in relation to modifications in quality, quantity, and utility of the resources and environments of those coastal waters resulting from the activities of man. In this effort the intention is to consider existing quality, trends in quality, existing water quality criteria, and the state of the art in establishing and evaluating the same. Ability to monitor will be examined also.

THE WATERS IN QUESTION

To accomplish the purposes projected above, we must first define the various components of the waters under consideration and examine them in some detail. It is only in the light of adequate factual knowledge about these waters that effective management can be cast!

Estuarine and Coastal Waters

While most of the legislation previously mentioned especially referred to and used the terms estuary, estuarine and estuarine zone it soon became clear that the coastal waters, those on the coast of the open ocean, also were involved. They, too, are intermediary between land and land drainage and the seas and oceans. Both estuaries and coastal waters must, therefore, be considered, if our management system is to be complete in its coverage.

ESTUARINE WATERS

The word estuary usually denotes a semi-enclosed body of water opening into or debouching from the ocean, receiving ocean waters and tides and, generally, contributing freshwater to the seas. This definition is rather broad. Some, for example Pritchard (1967), construe it more narrowly, restricting the term to those areas or reaches of tidal tributaries within which ocean waters are measurably affected by or mixed with freshwater from upstream.

Much discussion has been devoted in the literature to the various categories into which the estuaries and coastal waters of the world may be divided. A number of classification schemes for estuarine waters have been devised and published in various scholarly and technical papers, such as Williams (1962), Pritchard (1967), Clark (1974), and Odum, Copeland, and McMahan (1974). Many of the systems presented in those works are quite significant scientifically. While all of them are interesting and some are useful to management, a complete review of classifications is beyond the scope of this report. For our purposes it is sufficient to note the existence of the different ones, adopt one with utility, and move on.

Along with others who have considered the problems of managing the quality of waters of the coasts, I have found it expedient to simplify terminology. Consequently, in this essay the word estuary is construed broadly, covering all semi-enclosed basins and tributaries which interact with the world's seas and oceans (including the tidal bodies frequently classified separately, such as fiords, tidal rivers to the upper limits of tide, lagoons, brackish and saline bays and sounds, and others).

COASTAL WATERS

For all open coastal situations the term coastal waters suffices. Both estuarine and coastal waters interact with the land, with surface runoff and subterranean aquifers, and with man and his activities and properties. Both receive his effluents directly and indirectly. Both retain or transmit them to the sea or to the bottom. To protect the oceans, husband their qualities and uses, and properly serve present and future societies both must be effectively understood and managed. Adequate understanding is absolutely necessary for management! See especially the background materials commenting on these points presented in the NAS-NRC paper "Waste Management in the Coastal Zone," (NAS-NRC, 1970, p. 2).

Characteristics of Estuarine and Coastal Waters

The oceans, themselves, and the highlands (or fastlands) comprise about 95 percent of the surface of the earth. The waters and adjacent lowlands which interface between these two major geographical realms make up less than 5 percent of the total area of the globe. This is the "coastal zone." Comparatively minor in area, this small portion of interacting land, water, and air is highly critical. It is all-important to the condition and welfare of land and sea and of society. Like all such transition zones it is a dynamic and changing fraction—a zone of high energy flux.

FEATURES OF ESTUARIES

As indicated, many attempts at definition have been made and several classifications published The simple definition utilized here, i e. estuaries are bodies of water regularly connected with the ocean, within which measurable quantities of ocean water occur and/or which experience ocean tides, encompasses all known types occurring around the United States, from the several hypersaline lagoons (which receive only limited amounts of freshwater, have weak flushing action and contribute salty water to adjacent coastal areas) to the mighty estuary of the lower Mississippi River (which injects massive amounts of freshwater, sediments, and other materials into the northern Gulf of Mexico).

The fringing coastal bays, sounds and lagoons protected behind the barrier islands of the Atlantic and gulf coasts and the fresher, more elongate and frequently larger tidal bays and tributaries of all coasts also fall within the definition The Laguna Madre of Texas, the Carolina sounds, the seaside bays of Virginia, Maryland, Delaware, New Jersey, and Long Island are examples of the former (fringing coastal bays and sounds) Cook Inlet, the various fiords and river mouths of Alaska and the Great Northwest, Mobile Bay, Tampa Bay, Wynyah Bay, Charleston Harbor plus its entering tidal tributaries, the Ashley and the Cooper Rivers, Chesapeake Bay, Delaware Bay, the lower Hudson, the lower Charles plus Boston Harbor, and the Passamaquoddy—all fall within the latter grouping

These estuarine bodies occur at many latitudes (and longitudes on east-west oriented coast) in every coastal reach from the northern border of Maine to Brownsville, Tex, and from southern California to the North Slope of Alaska Hawaii and the far-flung commonwealths and territories contain them also, though island estuaries are usually very small This extremely wide geographical range has a profound effect on their diversity.

Obviously, with such a range of type, location, and size, estuaries are difficult to generalize about There are considerable differences in the sizes and slopes of the land areas they drain and in the geometry, hydrography, and biology of their watercourses

Too, estuaries are subject to varying prevailing atmospheric climates and weather in accordance with their locations, being subjected to widely differing patterns and amounts of rainfall, sunlight, and temperature See, for example, the maps, zonal concepts and classifications presented in USDI (1969 and 1970), Odum, Copeland, and McMahan (1974), and Clark (1974).

Geophysical features—Even within themselves estuaries contain different zones or reaches, as for example, a) the upriver, fresh, but tidal reaches occurring immediately below the fall line, b) the intermediate brackish transition reach which connects both oceanic and land-originating waters, and c) the near-oceanic zones at their mouths. Figures 1, 2 and 3 depict various features of a partially-mixed estuary which features partial stratification and two-way surface and bottom non-tidal currents (To the latter two reaches occurring at the lower ends of tidal tributaries the term estuary is restricted by Pritchard, 1969) Another classification applied to these reaches or zones is oligohaline, or low sea salts (0 5‰–8 0‰), mesohaline, or intermediate sea salts (8 0‰–18 0‰), and polyhaline or high sea salts (18 0‰–30 0‰) Thirty-five parts per thousand is standard full seawater salinity

Not only are these reaches, extending up and downriver, different but there are marked variations from side to side and from top to bottom involving such characteristics as currents, temperature, oxygen content, transparency, and other aspects. Too, these zones may move horizontally landward or seaward, or vertically toward the surface or the bottom, depending upon regular (seasonal, monthly, or daily) changes in tides or freshwater influx or abnormal winds, coastal surges or land runoff.

Just as morphological and physical aspects of estuaries and coastal waters are immensely complicated and ever-changing so also are their other features. In terms of structural and functional complexity—biologically, chemically and geologically—these waters have no natural peers They are extremely dynamic and productive.

Biological aspects.—In these chemically rich and fertile estuarine waters and the shallow oceanic areas into which they drain grow most of the marine biological organisms—the plants, marine fish, and shellfish that help nourish many peoples of the world. A large number of authors including Stroud (1971) have concluded likewise.

According to Teal, Jameson and Baden (1972) there were harvested from estuarine and shelf areas 10 billion pounds of commercial finfish and shellfish in 1970. Most of these fish are species which live in (at one time or another in their life stages) or are dependent upon these productive waters Were the figures utilized by Teal, Jameson and Baden (1972) expanded to include the amounts and kinds of animals and plants taken by recreational fishermen as well as those which are harvested for sale but unreported (undoubtedly a significant number!), the poundage taken would be even more impressive.

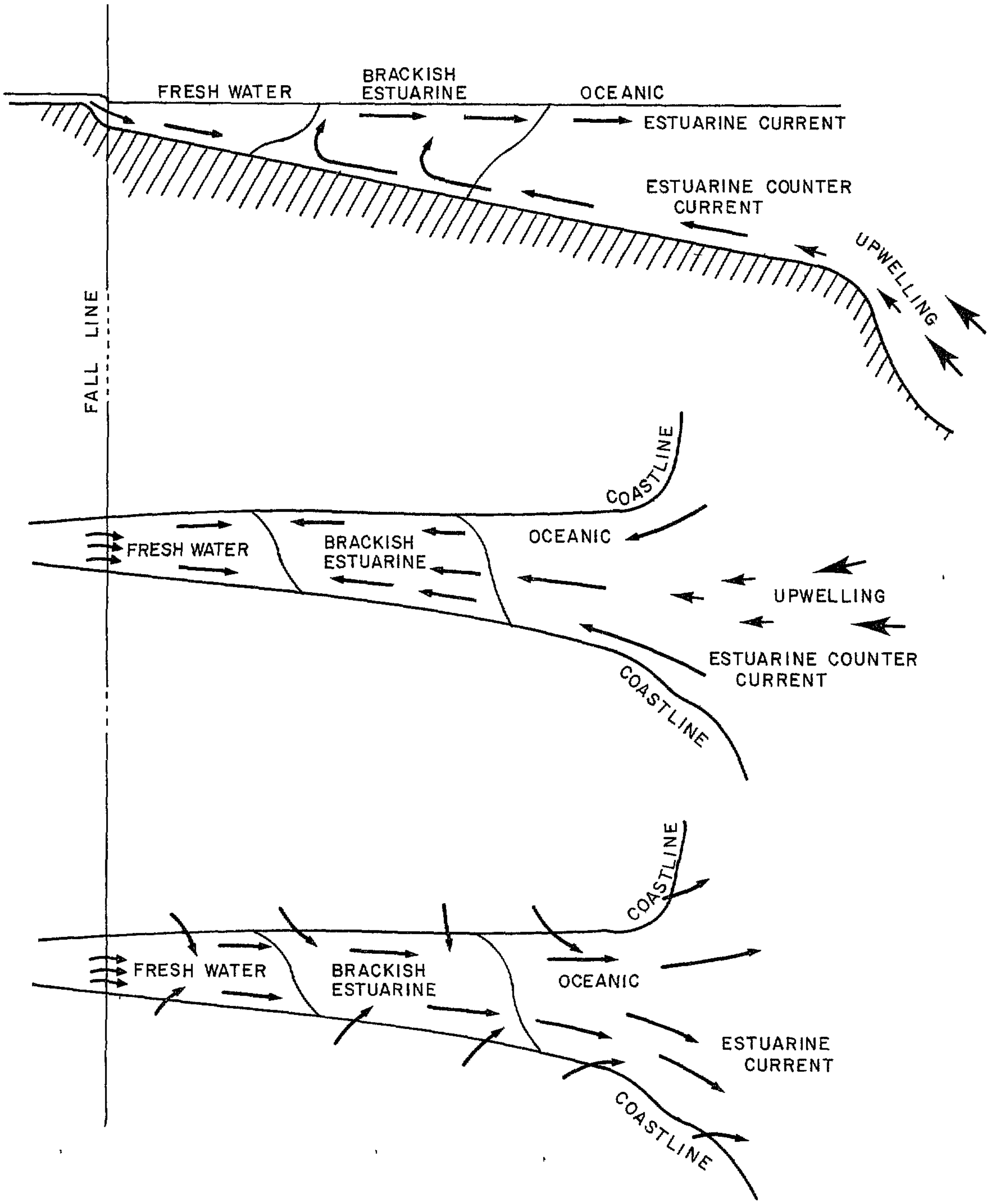

FIGURE 1 (top) —Tidal tributary—profile of mixed type FIGURE 2 (center) —Tidal tributary—partially mixed bottom circulation. FIGURE 3 (bottom) —Tidal tributary—partially mixed surface circulation

Of course, these figures do not incorporate the millions of tons of nonharvested animals and plants which grow in the waters of the coastal zone or feed upon their products and which nourish those that are harvested.

Bacteria, countless millions of phytoplankton and zooplankton plants, wetlands grasses, attached and sessile organisms all contribute to this tremendous productivity In any one estuary thousands of species may occur. Some have extremely complex patterns of migration and several life stages. For example, the blue crab (*Callinectes sapidus*) has separately identifiable stages and molts several times before reaching its final size. The young stages are planktonic while the adult, an active swimmer as well as walker, lives on or in the bottom most of the time. Their numbers and species composition change from year to year, season to season, day to day, between day and night, and even from hour to hour.

Their physiological activities and dependent environmental requirements are diverse. Some, like the hardy adult *Fundulus* can survive wide ranges of temperature, oxygen, and pollutants. Others are extremely fragile, like the larvae of the Atlantic oyster, *Crassostrea virginica*, which have been found recently by scientists at the Virginia Institute of Marine Science to be very sensitive to chlorine, with an LC_{50} of 0.005 ppm. in 48-hour bioassays. (LC means lethal concentration, referring to that concentration at which 50 percent of the individuals subjected to the substance being tested die within the time specified). Levels well above these (0.02–0.03 ppm) have been observed in the lower James estuary over a mile from the nearest sewage treatment plant outfall. In some species the adults are considerably different in habit, appearance, and resistance. For example, adult Atlantic oysters can tolerate much higher levels and appear to do quite well on beds in the same waters of the James, which contain chlorine concentrations two orders of magnitude above the LC_{50} established for larvae, (Huggett, R. J., personal communication).

Chemical aspects.—Natural chemical constituents of coastal zone waters are derived from land runoff, subsurface terrestrial drainage, interchange with the bottom and with oceanic waters, atmospheric fallout and precipitation, and from biological processes. The actual numbers of inorganic and organic molecules in estuarine (and coastal) waters are great. Even after decades of analysis many molecules remain to be identified; more must yet be properly and fully characterized. As with the biota, the kinds and amounts of chemical constituents vary considerably over time and with various weather conditions. Add the thousands of manmade compounds in varying mixes and concentrations contributed in sewage and industrial effluents and entering from the atmosphere and by land runoff, and an already complex and constantly changing chemical soup is further complicated.

Indeed, their natural complex and dynamic chemical systems are the features which render separation, or detection, and analysis of the various chemical components of these waters so difficult. This bears directly, of course, on difficulties of establishing meaningful baselines, criteria, and standards for many chemical constituents.

Geological aspects.—The geological processes of inshore waters are variable and varied. The amount of suspended matter (hence transparency and color), which includes particles of geological origin as well as microscopic plants and animals (the plankton), varies with, a) fluvial or riverine and lateral runoff, b) winds and currents, and c) biological processes and other hydrographic factors. It also depends upon the condition of the soils of nearby land masses.

High water flows caused by spring rains and thaws and by storms scour the upland river bottoms and adjacent lands. Downstream, estuaries run turbid with the reds or browns of dislodged soil particles. These particles are quite active in picking up and transferring chemicals, bacteria, and viruses from land to water, from water mass to water mass, and from water to bottom sediments and back again. In this way beneficial chemicals, i.e. necessary nutrients and trace elements, are brought into the system. Unfortunately, toxic molecules and microbes are also.

While dancing about in estuarine waters, suspended silt acts to "scrub" the water and to enrich it by releasing nutrients. Pollutants carried to the bottom by falling silt and stored in the sediments later may be recycled during periods of high turbulence induced by winds or currents. They can also be recycled and relocated by dredging and spoil disposal operations. Too, processes of erosion, transport, and deposition move geological materials up and down the estuary and from shallower to deeper waters (and vice versa where conditions are right). Estuarine sediments are carried on outgoing tides and currents into the waters of the open coast and the reverse may be true.

Eolian earth particles, generally with attached (or accompanied by) chemicals and plant and animal matter are deposited in estuaries. Fallout and precipitation also inject natural and unnatural atmospheric travelers. Some, like lead and its derivatives and radioactive particles, can be troublesome.

The biology and chemistry of shallow waters of the sea are closely dependent upon the geological activities mentioned above. Since these waters and their processes are all complex and varying, the resultant "broth" is likewise, contributing further to difficulties of understanding, definition, and control. Thus, they present great and growing problems to scientists, engineers, and management people alike. Great, because of the natural complexity and their dynamic nature. Growing because of the added contributions and pressures of burgeoning coastal populations.

Features of Coastal Waters

Outside of the mouths of the great bays and tidal tributaries and of the passes and inlets of the fringing bays, lagoons, and sounds lie the coastal waters. Shallow and turbulent, yet bordering on the depths of the oceans, these coastal waters are subject to effects of wind and of water injected into them from upland drainage and from the wetlands, estuaries, bays, and sounds they drain.

In the deeper passes and rivers and through the bay mouths a two-way flow exists with saltier shelf water flowing inward at the bottom while fresher and lighter estuarine water flows outward at the top. In some this flow pattern is reversed. In yet others the lighter, fresher water flows out at one side and the saltier, heavier water in at the other. Thus, coastal waters receive fresher estuarine and surface runoff waters (or saltier water from hypersaline embayments) as well as contribute directly to estuarine flows. Additionally, inshore coastal waters may be augmented by upwelling from deeper oceanic basins, by water masses moving alongshore, and by injections and meanders from powerful ocean currents like the Gulf Stream. As shown schematically in Figures 1, 2, and 3, all receive surface drainage and lateral flowage into their surface waters, to say nothing of injections from the atmosphere via precipitation.

In these coastal waters mixing is usually vigorous and large volumes of water are available; hence, quality as determined by dissolved oxygen is generally good. However, domestic and industrial outfalls dominate in some places. Where they do, quality is often poor. There are some locations, too, where circulation patterns may concentrate pollutants or flotsam and jetsam, which remain either offshore or move toward and onto shore. These places are usually unsightly or foul, or both. There are reaches of beaches where wave energy is focused into such strongly erosive forces that surface and subsurface structures are endangered by buffeting and erosion. (Goldsmith, V. G., personal communication). Obviously, such features would have to be considered when placing, building, and operating ocean sewage outfalls or in disposal of dredge spoils, sludge, trash, or other materials.

Semi-estuarine situations.—At places along the coast peninsulas and promontories may so restrict circulation as to produce semi-lagoonal or semi-estuarine situations. In such cases, assimilative and dispersive capacity may be restricted or reduced and the system may behave like an estuary or lagoon. Sewage outfalls and sludge deposits should not be placed in such coastal reaches unless slow dispersion or containment is desired.

People—Another Estuarine Concept

Coastal waters and/or estuaries have been established above as complex and dynamic natural systems in their own right. Neglected has been mention of people, people in concert—of society and its impacts on these difficult and fragile ecosystems.

The Effects of Man

As we have seen, even without society and its varying needs and wants and its changing demands and pressures, estuaries and coastal systems are sufficiently complex and dynamic to confuse comprehension and confound management. Add man and his works and the difficulties of understanding, working with, or managing them are magnified and compounded.

Society's demands.—Society has been living on the shores of the seas since before written history and long before the problem of waste management became a major concern. Society's demands on the environments and resources of the estuaries have grown and changed over the millennia as they are doing even today. Beginning with simple wants and needs, the demands of the small populations comprising early families and tribes and tribal confederations probably worked no significant hardship on estuaries. However, as engineering capabilities have developed and human populations and maritime industries have grown and changed, man's impact on the estuaries has magnified also. It is sufficient to point out here that the impacts of society on estuaries and coastal waters have increased markedly in size, number, and complexity and that they are dynamic, changing as society's needs, demands, and technological abilities do.

Man's activities, too, can only be roughly categorized and understood, at least partially, but their dynamic effects introduce a whole new dimension of difficulty into our attempts to understand the ecosystems involved. With man in the picture, estuarine and coastal ecosystems become increasingly difficult to understand.

Growth—one factor.—That most of the people in the United States live on the shores of the oceans and their tidal tributaries or of the Great Lakes has been stated and demonstrated many times. Further repetition is unnecessary. Sometimes neglected, however, is the fact that each year the populations of the coastal counties of the nation change in numbers, generally increasing ("The National Estuarine Pollution Study," USDI, 1969). Too, the specific demands placed on estuarine ecological systems vary from region to region, from estuary to estuary, or even within estuaries.

Time—the other factor.—One other natural factor plays a role in both coastal waters and society, that of long-term, one-way and normally irreversible change—evolutionary change. As do natural, undisturbed estuaries, societies undergo evolutionary changes as well as short-term modifications. Those alterations wrought by nature usually require longer periods of time, while those of man often require only a short time. Man-caused modifications are taking place at an increasing rate and are of growing magnitude as technological skills permit.

Long and short-term changes.—Superposition of the short-term, dynamic characteristics of estuaries and coastal waters with their daily, seasonal, and other cyclical changes upon the slower, largely unidirectional alterations of nature makes understanding and control difficult. Adding the alterations of man and his changing numbers, needs, and uses compounds this dynamism. In truth, estuarine and coastal ecosystems with their added burden of society are not only complex and sometimes fragile but they are variable and varying. Thus, even without man they are difficult to study, to learn, and to know. Add society and these difficulties are worsened. Man can make substantial changes even while conducting studies designed to learn how things were! These changes can so alter the nature of the system as to make new studies necessary, even before the old one is completed!

How can estuaries and coastal waters be understood?—There are certain basic similarities among the myriad and unique estuaries and coastal waters, to be sure. Similarities of structure and function, which can be used to develop understanding, principles, and models can be detected and described. By doing so, common factors of the classes, systems, and phenomena of estuaries and coastal waters can be ascertained and generalized frameworks for management, use, and preservation developed. But prescription of uses or the most economical and reasonable basis to meet the needs of nature and society can only be accomplished by a detailed local knowledge of each estuary or inshore zone and of each of its affected operational segments.

The Receiving Streams

Having established that coastal waters and estuaries are complex, dynamic, variable in location, extent, depth, and in other critical dimensions and that they are subjected to varying conditions of tides and climate and other features, it remains to establish clearly why these features are important to our purposes. It is because these are the receiving streams, the waters for the effluvia and rejecta of coastal societies (and even those far inland). And it is their absorbing, diluting, and modifying powers which, coupled with the contaminants and alterations of man, will determine the ultimate questions of quality within coastal zone waters or even far at sea—of whether or not pollution exists and its extent.

UNDERSTANDING FOR MANAGEMENT

These waters, therefore, must be understood and that understanding must be utilized in any sound program of water quality (or wastewater) management. Obviously, all of the factors mentioned above, natural and social, must be known and considered when water quality criteria are being developed, when standards are established, when control and monitoring schemes are projected, and when projects for industrial development, recreational development, utilities, housing, and other activities are being planned, sited, constructed, and operated.

The biological, chemical, geological, and physical characteristics of estuaries and coastal waters and the realities of social activity on the coasts will ultimately determine not only the nature of the uses to which these environments can be put without severe damage to them and to society but also determine the costs.

Economics also must be considered. Under current conditions of world wide economic stress it is apparent that every effort must be made to maximize the productive uses to which marine resources and environments can be put while retaining their utility, viability, and potential. The food, minerals, recreational, and aesthetic aspects and the cooling and absorptive properties of estuarine and coastal waters are of great economic value!

Variation and environmental management.—Thus, estuaries, which in reality are complexes of natural ecosystems and ecotones (smaller zones of transition between ecosystems), are extremely varied and variable. Because of their variety and changeability and their wide variation in size and location, estuaries are hard to generalize about, to know, or to deal with as a group or in classes. They are almost as variable and difficult as human individuals and present similar difficulties to students and managers alike. Groupings can be made, but in the last analysis they must be understood and managed as individuals. Doing so poses massive problems and great strain, and requires considerable knowledge, care, and skill. Careful environmental and resource engineering is required. Management must be sophisticated and well-equipped with technological capability. It must also be well-staffed and provided with scientific knowledge of the environments and resources involved and of society's needs and demands. A close interaction between management and science and engineering is required. Unfortunately, at present there are many shortcomings in the ability of each to respond to the problems. Not the least of these is a lack of understanding of the complex and dynamic environments and resources which we seek to utilize wisely or of the "real" present and future needs of society.

WATER QUALITY ASPECTS

It is not within the province of this essay to comment in detail upon possible organizational arrangements for management or for all of the myriad scientific and engineering activities required to determine how much of man and his various demands the environments can tolerate and support. Instead, it is our task to evaluate trends in the quality of estuarine and coastal waters, to examine existing water quality criteria, and to evaluate the state of the art in establishing and evaluating water quality and water quality criteria.

Quality of Estuaries and Coastal Waters

Many authors and groups have examined and commented on quality of marine waters in the last two decades. Their pronouncements range from doomsday statements (such as the public pronouncements made by irresponsible, unfettered environmentalists) to euphoric, optimistic ones (such as those propounded by some industry spokesmen or development-oriented propagandists). As frequently happens, the truth seems to lie somewhere between the two extremes. However, there can be little question that man and his demands are pressing the resources and environments of the coastal margins of the World Ocean—and heavily.

CLASSIFICATION AND QUALITY

Findings of "The National Estuarine Pollution Study."—This work (USDI, 1969) divided coastlines, the United States, and its commonwealths and territories into the 10 biophysical regions depicted in Figure 4. It then proceeded to typify the classes of estuarine and coastal waters within each region and to discuss their condition.

It would be profitable to examine anew and in detail the conditions of uses, modification, and the quality in each of these 10 zones and to conduct a thorough review of all estuaries and coastal waters included; however, restrictions of time and space do not allow it. Fortunately, we can utilize previous work.

"The National Estuarine Pollution Study" did find that 25 estuarine systems (page II 60), including Penobscot Bay, Boston Harbor, New York Harbor, Raritan Bay, the Delaware Estuary, Baltimore Harbor, the upper Potomac, the James, Charleston Harbor, San Juan Harbor (P.R.), Tampa Bay, the lower Mississippi Laguna Madre, San Diego Bay, Puget Sound, Silver Bay (Alaska), and Hilo Harbor (Hawaii) "show definite documented water quality degradation as a result of human activities." It further stated that for "38 percent of the systems of the United States there is a lack of information to allow judgment of whether there is ecological damage, or whether there are just no easily identifiable problems present"—yet.

The report proceeds to point out that, "Wherever people live, work and play in the estuarine zone the demands of their social and economic activities place stresses on the biophysical environments. These stresses frequently result in degradation of that environment, perhaps not immediately or even in a few years, but nonetheless certain in its devasting final impact."

The study continued (Page II 61) "The complex nature of pollution in the estuarine zone (Author's note—used broadly in that study to include all tidal coastal waters as is done herein) prevents the separation of sources of pollution, kinds of pollution and types of environmental damage into neat compartments of cause and effect. All of human activities in the estuarine zone can damage the environment and most of them do." The report imparts a decidedly negative impression of the condition of the Nation's estuaries.

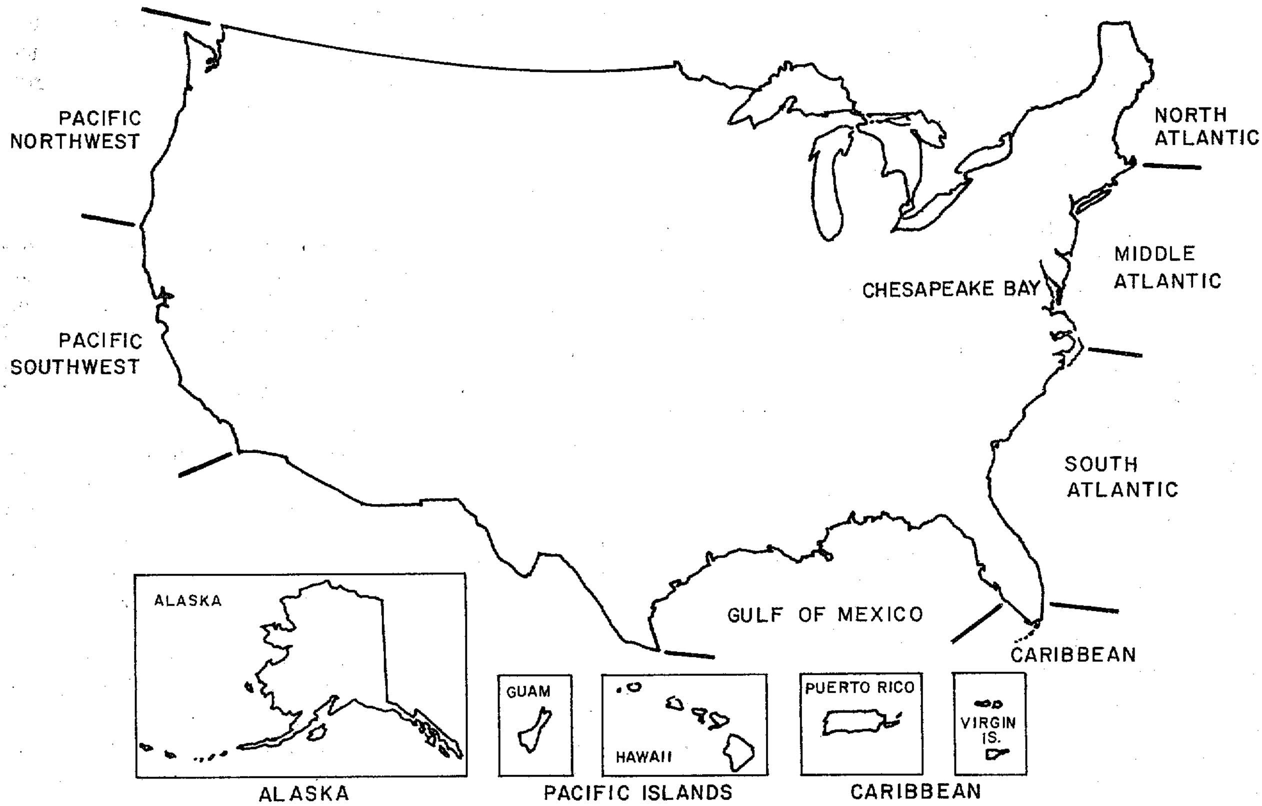

FIGURE 4.—Biophysical regions of the United States (from The National Estuarine Pollution Study, U.S.D.I., 1969).

Whether one subscribes to this somewhat dismal and dismaying conclusion, there is no question that for each use to which man puts these waters there is a cost in quality or quantity or both. The objective of good management is to arrange it so that our uses and demands absorb only what nature can spare—that we use only the overage or excess, the interest and not the principle. We must be "good" parasites and not kill the host.

Findings of "The National Estuary Study".—After developing a series of interesting color-coded maps depicting the condition of estuaries and coastal waters according to whether they were: 1) relatively unmodified, 2) moderately modified, or 3) severely modified, this effort (USDI, 1970) presented a table illustrating the degree of modification of estuaries. Like the chart previously mentioned (Figure 4) this table (adapted for use herein as Table 1), utilized biogeographic zones. Of all of the American estuaries and subestuaries reviewed, 23 percent were severely modified and 50 percent were moderately modified while only 27 percent were slightly changed. Thus, in the opinion of the preparers of that study, a large majority (73 percent) of the estuaries and subestuaries in the United States had been moderately or severely modified by man. Even though some of the modification described is in the form of summer-home encroachment on scenic areas (an activity whose damaging impacts are often difficult to establish or qualify), this is a staggering percentage considering the fragility of estuaries and their importance to the adjacent seas and to the economic and social welfare of man. Much of the modification recorded by this study, directly relates to the problem at hand—degradation of water quality by pollution and modification.

Good is not good enough!—It is possible to find weaknesses in both studies and in all other such nationwide, general evaluations. It is easy to point out that some of these systems are naturally "dirty;" that they were on the evolutionary road to oblivion long before the industrial and technological revolutions began and the population pressures of today developed. We can even point with pride at the efforts being made to eliminate or reduce toxicants, nutrients, and harmful changes—and we should!

Table 1.—Modifications of the Nation's estuaries.[1] Most estuarine areas of the United States have been modified more or less severely by man's activities. The degree of modification is indicated by regional zones in the following table:

Biogeographic Zone	Degree of Modification of Estuaries[2]		
	Slight	Moderate	Severe
	Percent		
North Atlantic	44	48	8
Middle Atlantic	5	68	27
Chesapeake Bay	44	50	6
South Atlantic	36	60	4
Biscayne and Florida Bay	50	50	0
Gulf of Mexico	15	51	34
S.W. Pacific	19	19	62
N.W. Pacific	13	50	37
Alaska	80	20	0
Hawaii	54	15	31
Great Lakes	35	46	19
United States	27	50	23

Source: Field evaluation carried out by Fish and Wildlife Service's personnel during course of Estuary Protection Act study.

[1] From the "National Estuary Study" (U.S.D.I., 1970)

[2] All estuaries and subestuaries were individually rated for each zone. The percentage refers to the proportion of these individual areas that were rated as indicated.

The condition of some estuarine areas has been improved or the rate of degradation altered, as for example the upper tidal Potomac, New York Harbor, and San Francisco Bay. There must remain, nonetheless, the conclusion that the best that we have done or can do under present conditions of knowledge, technology, and commitment is not enough. All of the signs available today indicate that the quality of estuaries and coastal waters continues to decline. We are making 3 knots against a 4 knot current. Our water quality management effort is making "sternway"—more slowly than without the effort, but sternway nevertheless. We are still losing!

It is to be expected that the current economic downturn and the lowering trend in population growth will slow the rate of degradation or modification of estuarine and coastal environments and resources but it is doubtful that progressive degradation will be stopped until knowledge and control techniques and arrangements improve markedly. Pressures of the coastal zone continue to grow as the population of the United States rises (by births, decreasing mortalities, and immigration) and especially as the populations of the counties, cities, and towns in the coastal zone grow due to the continuing coastward movement of people. We have not yet learned how to establish carrying capacity of specific land areas or river basins or how to control population levels in specific regions. We must! Indeed, there is as yet no general agreement that in some places or at certain rates and levels, growth becomes a problem, one which must be directly attacked and solved. We talk of food and resource shortages and environmental problems, but never seem willing to face its root causes—too many people, too many demands. We seem to have a blind side when it comes to population and to growth. We still generally seem to believe the more the better, even if not the merrier. This abysmal attitude is discouraging.

It is not possible to agree, however, with the doomsayers that the oceans must die in a decade or three or even five decades. Nor is it possible to agree with those who apparently believe that man has no right to occupy the coastal zone or to use or modify its resources and environments. Both conclusions seem overdrawn. The last is foolish! Man, too, is a product of nature, of the evolutionary process, and belongs naturally on planet earth. It is necessary to conclude, however, that the quality of the coastal zone is being degraded and that we have neither learned to appreciate and apply the well established concepts of carrying-capacity, nor how to match ourselves with nature—nor to understand and manage either well. Much must yet be learned!

Existing Water Quality Criteria

The conclusion that the United States continues to lose ground in its fight to reverse the trend of degradation of estuaries and of coastal water does not detract from the positive efforts that have been made at the federal level, by Congress and the Executive, by state legislative and executive authorities, and even by many regional and local bodies. Fruitful efforts to improve management capabilities have gone forward under the several acts mentioned above. Most states, counties, and cities have increased their efforts at controlling pollution and engineering and there has been general improvement. As pointed out above, some estuarine areas have been partially cleaned up. In others, the progress of degradation continues with little abatement.

Among the efforts that have contributed positively to our increasing control over the factors affecting water quality have been the Water Quality Criteria developed by the National Technical Advisory Committee (NTAC, 1968) and the several panels of the Water Quality Committee of the Environmental Studies Board of the National Academy of Sciences-National Academy of Engineering (NAS-NAE, 1973).

The Environmental Protection Agency has also recently developed suggested criteria (EPA, 1974). These will be considered in order.

THE NATIONAL TECHNICAL ADVISORY COMMITTEE

Based upon a review of published data and conclusions, and including even unpublished data, a group of scientists and engineers familiar with the various problem areas was gathered, to accumulate, evaluate, and summarize a wide range of the existing knowledge related to water quality with the purpose of establishing water quality criteria and recommendations for management. The results of their considerable effort were published in 1968 and the report quickly became known as "The Green Book" (NTAC, 1968a). Of course, the NTAC owed much to earlier encyclopedic efforts such as those by Vinogradov (1953), McKee and Wolf (1963), and to many technical papers produced by previous workers.

The Results.—In addition to addressing the water quality requirements for the various broad categories of uses to which natural waters are put, or for the aquatic resources on which the various uses may be based, the Advisory Committee considered certain details of the many pertinent sampling and analytical procedures.

Within these categories of uses and the resources on which those uses depend, many species of chemicals and groups of manmade contaminants were considered. These included toxic or damaging chemicals, oils, and heavy metals, as well as other factors, for example, nutrients, turbidity producers, and color modifiers.

Summaries of the demands and requirements for water by various major industrial activities considered were also provided in "The Green Book."

Specific criteria and standards.—Specific criteria or recommendations for management of quality were developed where possible. Unfortunately, the water quality criteria established by NTAC were too quickly converted by the authorities responsible into "Standards." The word "unfortunate" is used because in the rush to develop those standards the caveats so clearly specified by the committee in preparing the report, were ignored. They were restated by J. G. Moore, commissioner of FWPCA, in his letter of transmittal to then Secretary Stewart L. Udall; Moore pointed out that "Regional variations in climate, typography, hydrology, geology, and other factors must be considered in applying the criteria offered by the Committee to the establishment of water quality standards in specific localities" (NTAC, 1968a). However, the criteria were transmitted quickly into standards of control for wide geographic application. Several other cautionary notes or warnings included in the report were apparently unheeded. As a result, many of the standards prescribed are impossible of attainment.

Mixing zones and zones of passage.—Too, the Committee addressed itself to other problems related to management of water quality in estuaries and coastal waters such as "mixing zones" and "zones of passage." These two subjects are quite important since as long as there are effluents to be released there will be mixing zones and the problem will be to keep them limited in extent and number to the bare minimum required.

Limitation of mixing zones is necessary to allow multiple use of the waterways in question and survival of the fish, wildlife, and other species of the normal biota so vital to the economic and aesthetic activities of man. Additionally, effluent mixing zones must be so arranged within an estuary (or along the coast) as to allow adequate zones of passage for species which must travel (or be transported) up and down stream or along shore, such as herring and shad, striped bass, and most other coastal and/or estuarine-dependent fishes. Pelagic larvae of oysters and clams and a host of other ecologically or economically important shellfish are also involved.

Research Needs for Water Quality.—In addition to the water quality effort, the National Technical Advisory Committee also reviewed the research needs related to establishing and improving water quality criteria and standards and for monitoring natural and modified aquatic systems. Its report, "Research Needs" (NTAC, 1968b) was published after "The Green Book" appeared. Unfortunately, its recommendations have not been well-heeded and much of the important research and development activities urged in that report has not yet been accomplished.

THE NAS-NAE ENVIRONMENTAL STUDIES BOARD

The efforts of the various panels of the Environmental Studies Board of the National Academy of Sciences-National Academy of Engineering seem to have been patterned after the work of the NTAC. This activity, conducted under a contract from the Environmental Protection Agency, resulted in a voluminous report which is, not surprisingly, coming to be called "The Blue Book" because of its striking blue cover. The report utilizes the same broad categories of water uses and water-dependent resources (aquatic life and wildlife) as did the NTAC effort. Too, the NAS-NAE report makes recommendations for management guidelines and criteria for the various classes of contaminants and the important chemical molecules known or believed to be of importance in water quality.

Improvements over earlier efforts.—"The Blue Book" effort of NAS–NAE included far more data in its presentation, than did that of the NTAC. Of course, the NAS-NAE panels had the benefit of several more years of research but they also seem to have been able to encompass more of the available data than the 1968 study did. Review of the report in preparation of this article, confirms the statements of Drs. Handler and Linde, presidents of the National Academy of Sciences and the National Academy of Engineering respectively, which said, "The 1972 report drew significantly on its 1968 predecessor; nevertheless the current study represents a complete reexamination of the problems, and a critical review of all the data included here."

Shortcomings.—While generally a significant improvement upon the earlier NTAC work, the 1972 report has some shortcomings. For example, "The Blue Book" fails to address the possible water degrading effects of modifications of the various geophysical parameters, such as: a) bottom topography, depth, and shoreline contours by dredging and spoil disposal; b) shoreline contours and basin cross-section by shoreline filling or cutting; c) current modifications as by training wiers; and d) inflow changes as by impoundments and diversions of upstream waters. As the NTAC study pointed out in "The Green Book," these modifications may have profound effects on such important factors as circulation patterns, tidal patterns, and salinity levels, among others. The significance of modifications in the natural order of things caused by these activities, both by themselves and in concert with introduced contaminants, has been treated by a number of authors. (See for example the works of Hargis, 1966 and 1972; Chapman, 1971, and others, as well as the appropriate sections of the NTAC report).

These aspects have also been ignored in the development of many of the various water quality standards by the states and EPA. Perhaps this is because many state water quality management organizations do not have primary jurisdiction over channel dredging or water diversions or similar engineering-type projects. Nonetheless, a salinity or current change induced by the deepening of an estuarine channel or by diversion of freshwater inflow can have as far-reaching effects on water quality, on fishery and wildlife resources, and on users as any chronic contaminant.

A basis for revised criteria and standards.—Despite these criticisms (and there likely could be others) "The Blue Book" should provide a broader and firmer basis for specific improvements upon the criteria and standards developed in earlier efforts. It will be necessary for the standards-setting agencies such as EPA and state governments to consider well the qualification stated in the general introduction, to wit: "The Committee wishes to emphasize the caveat so clearly stated in the introduction to "The Green Book." The Committee does not want to be dogmatic in making its recommendations. They are meant as guidelines only, to be used in conjunction with a thorough knowledge of local conditions." In other words, the Committee can be interpreted as saying that these recommendations and criteria should not, indeed cannot be, automatically adopted as nationwide, regional, or even statewide standards.

EPA's Proposed Criteria for Water Quality

Following the work of the NAS-NAE Committee on Water Quality, EPA prepared its own report ("Proposed Criteria for Water Quality," Volume I and "Water Quality Information," Volume 11, 1973) in partial fulfillment of the provisions of Section 304(a) of the Federal Water Pollution Control Act Amendments of 1972. According to Volume 1, page 12:

> Water quality criteria as compiled in this document are defined as the acceptable limits of constituents in receiving waters based upon an evaluation of the latest scientific information by the Environmental Protection Agency. They are to form the datum for the Agency's 1983 interim goal of improving the Nation's waters to a quality that provides for the protection and propagation of fish and wildlife, and for the health of humans in their pursuit of recreation in and on these waters.

An EPA Comparison of Criteria

The EPA Document, "Comparison NTAC, NAS and Proposed EPA Numerical Criteria for Water Quality" (EPA No. 449, no date, probably 1974) comprises a comprehensive tabular comparison of those criteria which can be presented in numerical form or as brief narratives. It is based upon all three documents mentioned above, i.e. the NTAC "Green Book," the NAS-NAE "Blue Book" and EPA's "Proposed Criteria for Water Quality" and is useful in drawing a great deal of data together, allowing a quick comparison.

In general, a review of these new EPA documents indicates that the current proposed EPA criteria are based closely upon those presented in "The Blue Book." This seems an acceptable procedure since the NAS-NAE effort is the most recent and complete compendium currently available, as far as this author is aware.

Missing parameters.—Unfortunately, several of the significant chemical parameters such as nitrates, nitrites, phosphorous, salinity, and others, are not indicated in the EPA Criteria even though one or the other (or both) of the two basic compendia of criteria (NTAC, 1968a and NAS-NAE, 1972) did think them sufficiently important to examine and mention. This lack should not deter states, or EPA for that matter, from addressing these ecologically and economically important features.

Development of Standards

The purpose of criteria is to provide a basis for development of standards and management procedures. However, the cautions expressed above regarding the universal applicability of any of the previously developed criteria for adoption or modification as standards must be considered. Standards developed directly from criteria without due care of their limitations for use in specific locations or situations cannot, indeed will not, be adequate. The ills of estuaries and coastal waters, like human health, must be managed on an individual basis. Too, as will be seen, many of the data currently available and used in developing criteria and standards are not especially well-verified nor is their significance known. In many instances sufficient data are lacking. All of these factors present very real limitations upon criteria and upon standards developed from them and future revisions in both will be necessary. Like many current medical data and practices, however, they are the best we have to work with, and the patients (the marine waters in this case) have problems and must be treated now!

The State of the Art: An Examination

Having concluded that the water quality criteria developed by the three groups mentioned above are probably the best that could have been achieved by any reasonable national effort, examination of the foundations on which they are based is necessary. To develop the most effective and least costly management effort possible requires, among other things, standards that reflect reality as accurately as possible. Poorly founded standards place unnecessary burdens on the user and his customers, if any, (if too high) and on the public's environments and resources (if too low). Like other types of engineering, environmental engineering must be based on reliable or "real" data and it must be done to as close tolerances as possible!

All three of the groups involved with developing national criteria had to deal with certain difficulties, though NAS-NAE and EPA had fewer to handle than did the NTAC—the pioneer group. Each was faced with formidable tasks of attempting to accumulate and evaluate data from many sources within restrictive periods of time. The NTAC effort probably suffered most in this last respect; its working life was limited to a few months.

ADEQUACY OF BASIC DATA

The data that are available are variable in statistical and analytical reliability. Frequently, it is difficult to validate them, even with adequate time. Under pressing time constraints a great deal must be taken on the reputation of the author or institution performing the work—or on pure faith!

Status of scientific knowledge.—Actually, the coverage by science of the various chemical, physical, and biological parameters involved in water quality is variable. Some have been well investigated—some only superficially. Fortunately, the coverage and the competence of that coverage has increased rapidly in the last decade, but serious gaps remain.

Analytical weaknesses.—It is extremely difficult to detect many of the possible harmful chemical constituents in estuarine and coastal waters because these waters contain so many natural chemical substances. As the analytical chemists aver so colorfully, these waters are extremely "dirty." Often, the contaminants involved are effective or toxic in extremely minute quantities, (i.e. tenths or hundredths of parts per million or even tenths or hundredths of parts per billion). Too, they are frequently so similar to natural constituents of tidal waters that they are difficult to separate analytically. Also, they may appear, do their damage, and be removed by natural processes of sedimentation, flocculation, circulation, or dilution. Because of these problems effective analyses are difficult.

For some chemicals, techniques of detection are still poor. In other words, analytical methods are weak or they are cumbersome—requiring specialized equipment or skills. For many chemical constituents, only especially well-staffed and equipped laboratories are competent. All too frequently, enforcement laboratories are neither. The same may be said of some institutions engaged in basic research involved in generating the data which are later incorporated into reports such as those under discussion.

Standardization weaknesses.—Standardization of sampling, analysis, and reporting is weak. It is, therefore, difficult to compare results or evaluate them. In addition to all of these negative factors, instrumentation and other facilities for sampling in the field and laboratory, are in many instances, poor or nonexistent. An excellent example is the lack of readily available reliable and rapid analytical techniques for detection of chlorine and chlorine by-products in estuarine waters. Standard chemical techniques are poor and instrumentation weak. Only in the last year has there been a promising breakthrough in this area due to joint efforts of the National Bureau of Standards and the Virginia Institute of Marine Science (R. J. Huggett, personal communication).

To the all-too-frequent incompetence of specific sampling and analytical groups must be added the extreme variability and dynamic nature of the estuarine and coastal waters, themselves. These aspects were discussed in detail above.

Sampling and experimental difficulties.—Estuarine and marine animals and plants are difficult to sample effectively in nature. Statistically significant samples are hard to secure. Laboratory experimentation is even more difficult since the organisms involved often have complex life cycles with several stages, some of completely different habits. It was pointed out earlier that adult oysters are sedentary but the spawn of many species are discharged into the water. Many of the larvae are free-swimming. The larval, free-swimming stages are more susceptible to adverse water conditions than are their sessile parents.

Few marine species have been effectively held in the laboratory even for one life stage, much less for a complete life cycle. Far fewer have been reared or cultured under controlled conditions. Laboratory lines of known genetic makeup and environmental history (as for example in the mice or rat populations so dear to the hearts of medical experimenters) are almost unknown. Unfortunately, little effective sustained effort to overcome these weaknesses is in progress.

Weaknesses in bioassay data.—Many of the estuarine and marine criteria adopted by NAC and NAS-NAE are based upon bioassays conducted on freshwater species alone. Often those done with actual marine and estuarine species have utilized only the most hardy, the most difficult to damage or kill. It is desirable, as EPA workers have said (EPA, 1973), to base criteria and standards on the most important (importance is defined in several ways, i.e. in numbers, economic importance, position in food chains and others) species in the estuarine or coastal system for which they are being developed. This is an objective rarely attained! As a consequence, criteria and standards are often based upon extrapolations from less important and tougher species.

The uncertainties devolving from these shortcomings render certain of the current criteria and standards of dubious validity or significance. Too, the safety factors involved in extrapolation to account for and cover the basic weaknesses in the data are extremely high, often placing severe economic burdens upon the users who must engineer to meet the standards.

Criteria for certain biological contaminants.—The above described difficulties occur in many of the chemical analyses (organic and inorganic), environmental observations, and bioassays utilized in management of estuarine and coastal waters. But nowhere is the data base as weak as those on which the criteria and standards for pathogens, fungi, bacteria, and viruses, must be founded. There are many basic unknowns concerning the viability of viruses in natural waters. This is especially true of viruses in estuarine and coastal waters (Vaughn, 1974). The same applies, but to a lesser extent for bacteria where the significance of the basic examinations, measurements, and standards have been in question for almost 20 years. Despite its human health significance and importance to quality control, this aspect of water quality has been badly neglected. The criteria and standards suffer accordingly. Much additional work is required. Unfortunately, few research laboratories are equipped or staffed for (or concerned over) observations and experiments in this area. Apparently, many local, state and federal water quality laboratories are weak also. The number of competent microbiologists and microbiological technicians with experience working with estuarine and coastal waters is believed to be small

This lack of interest and broad capability with such important health-related factors is especially troublesome Unfortunately, no good techniques for sterilization or removal of viable viruses from effluent waters now exist (Vaughn, 1974)

There are many other areas of weakness in basic understanding of the factors important to effective water quality management.

BASELINES

Given the complex and dynamic nature of the waters under consideration and the vast volumes and areas involved, it is little wonder that baseline knowledge, or understanding of the natural ambient conditions, is not strong Until recent years effort in the field and laboratory has been spare and weak To be sure, conditions have improved in the last decade-and-a-half, but holes in the data remain A number of the estuaries and coastal waters of the United States have been investigated, but many have not As an example of the magnitude of the task involved, the Chesapeake Bay has been the home and arena of activity for what has been probably the largest aggregation of estuarine scientists in the world since before 1950, yet much remains to be done As an example, among the several institutions involved have been the Chesapeake Biological Laboratory at Solomons, Md., and a part of the University of Maryland, the Chesapeake Bay Institute of The Johns Hopkins University in Baltimore, Md , the Virginia Institute of Marine Science at Gloucester Point, Va , the National Marine Fisheries Service Laboratory at Oxford, Md ; the Environmental Protection Laboratory at Annapolis, Md , Old Dominion University in Norfolk, Va., the Westinghouse group at Annapolis, and the several state investigative units in both Maryland and Virginia. Other institutions and individuals have been active

CONCLUSIONS CONCERNING PRESENT CRITERIA AND STANDARDS

Clearly there must be shortcomings in existing criteria and standards since they are based, in part, upon the current, somewhat inadequate baseline knowledge of a) the environments involved and b) the requirements and tolerances of those environments and of the animals and plants living therein or dependent thereupon For some parameters, these shortcomings such as uncertainties over the fate and significance of petroleum hydrocarbons, halides, heavy metals, viruses, and bacteria are serious! Others are understood better

Standards and local knowledge —Standards should be based on competent local knowledge using the nationally developed criteria as a guide In most instances, the level of knowledge required is very high and quite detailed for a specific localized environment Frequently, information does not exist or is weak Most often, data have been hastily gathered, covering only a short span of time Given the nature of biological cycles and the seasonal and annual variability of precipitation over estuarine and coastal systems (and the extreme perturbations (i e wet or dry) and other extreme weather phenomena) many of the observations now available for use in design and operation of industrial plants and sewage outfalls are weak Inasmuch as this ignorance introduces uncertainties into the criteria, standards, and permit systems that obtain, and since engineering to cover those uncertainties requires much effort and cost, if one must overdesign and overconstruct, adequate baseline knowledge is important! Examination of the current situation indicates that much additional effort directed toward improving our baseline knowledge is required

Monitoring

Even after water quality criteria and standards have been developed and programs for construction and operation of treatment plants are under consideration—or actually in being—more remains to be done Public and private managers must track and learn the amounts and characteristics of discharges and they must determine the condition of the environment and biota on a frequent, even continuous basis Monitoring capability is required! Without it it is impossible to evaluate success or failure of the management program, to establish blame, or to rectify problems.

Monitoring requirements —For monitoring to be effective, it must be timely, accurate, precise, and complete in coverage For many parameters it must also be frequent and regular Its reliability should be assured

Monitoring limitations —Unfortunately for management, the same factors which made baseline development and bioassay difficult also plague monitoring efforts. In situ monitoring instruments of reliable quality are not readily available at reasonable cost even now. Analytical techniques are inadequate and adequately trained technicians are sparse. The salaries of water-treatment technicians are frequently too low to attract people of the required level of training and reliability. Management of treatment facilities is often weak.

All too frequently public water quality control agencies are forced to rely on effluent data gathered and supplied by the discharger. Properly controlled, this obvious shortcoming need not be too damaging but often there is no adequate followup or check. Without adequate checking such self-monitoring by dischargers must always be suspect. Many treatment plants are plagued by chronic overloads, poor management, and inept personnel. Breakdowns in equipment and procedures are frequent and the "midnight valve" appears to be the ready resort of operators with troubles.

It is not unusual that the public agency whose task it is to provide management-level surveillance or monitoring of effluents in estuarine and coastal waters, is poorly prepared to do so. These weaknesses are unfortunate because:

> The effectiveness of water management programs depends in major part on the scope, accuracy, and precision of the characterization of both the waste sources and the receiving waters. Rational waste control systems and facilities cannot be developed and operated without accurate information on the significant sources of waste, and on their relation to the receiving water characteristics established for protecting the beneficial uses. Only in the light of this type of information can the limited financial resources available for waste control measures be effectively allocated.

The preceeding quotation is the paragraph that introduced the excellent chapter dealing with monitoring included in the NAS-NRC (1970) study entitled "Waste Management Concepts for the Coastal Zone." The reader is referred to that document for a more comprehensive treatment of the problem.

The NAS-NRC Committee examined the needs of monitoring carefully and in detail. Others have recently addressed the problems of monitoring marine pollution at a workshop sponsored by the National Oceanic and Atmospheric Administration in southern California (Goldberg, ed., 1972a). Their results confirm the opinions expressed above.

A Summary of Shortcomings

Weaknesses.—There are, then, weaknesses in our basic understanding of the estuarine and economic environments and of the resources with which we are concerned. Not only are there weaknesses of fact and of extent (detail, comprehensiveness, range) of basic understanding but also of technique. Our ability to conduct meaningful bioassays, using those marine organisms that are really critical (as opposed to being hardy and amenable to handling), to detect and analyze many natural and manmade substances, to provide effective instrumentation, and to mount adequate monitoring capability must be strengthened! Otherwise, baseline knowledge, criteria and standards, planning, operating, monitoring and enforcement will continue inadequate.

Improvements.—Sufficient improvements in these areas have been made in the last decade and a half to allow greater confidence in present criteria, standards, and management capability. We are doing better and can improve.

Research needs.—Unfortunately, we lag badly in support of meaningful background research, in development of better treatment techniques, and in training personnel and staffing waste treatment facilities. Improvements in these aspects are possible also—even now!

New forces.—New forces are upon us such as: a) the increased apparent need to develop new sources of energy by bringing Outer Continental Shelf oil and gas supplies into use; and b) the need to develop more nuclear generating plants, and other water-affecting energy facilities. In the meantime, with inflation and a declining economic situation, pressures to reduce or eliminate controls and management efforts, which undoubtedly add to costs of development and use, are growing! It is a great temptation today to forget environmental safety in order to reduce costs to meet an emergency of money, energy, and time—especially when many other countries have done so. To do so would be extremely foolish and short-sighted! We must resist the pressures! This can be done in part by increasing knowledge, tightening quality control specifications, and managing to closer quality tolerances.

Zero discharge—a nonviable concept.—It must be noted at this juncture, however, that the zero-discharge concept of waste disposal and the urge and effort to release to the environment effluents which are "purer" than the natural waters of the receiving stream are not reasonable or viable concepts. Both ideas have contributed to: a) the antipathy that the clean-water movement receives; b) a lessening of legitimate efforts to acquire much needed knowledge; c) a weakening of the development of improved effective management; and d) a certain false sense of security and accomplishment in legislation and regulation. This is not to say that it may not be technically possible to accomplish such objectives but it will be extremely costly for society to do so—even unnecessary.

A point of urgency!—Hopefully, the current economic downturn, the urge for economy in government, and the strong thrust for development of new energy sources will not result in reversal of the recent trend toward improving the ability to prevent pollution, or rather to contain it within reasonable bounds. We cannot afford unnecessary expenditures of money to achieve levels of environmental control beyond those actually required. Neither can we allow degradation of environment or unfettered use of resources!

CONCLUSIONS

The Current State of Estuaries and Coastal Waters

Headway in development of standards and controls and greater public awareness and concern has led to considerable improvement in ability to slow, even prevent, contamination of estuaries and coastal waters. Older cities, located on estuaries or coastal waters, such as Richmond, Va., and Washington, D.C., have stopped spewing raw sewage into the upper James and upper Potomac, or are supposed to have. The volume of untreated sewage and the level of treatment have both changed for the better in most places. However, in certain, even most, estuaries the trends of degradation continue and at a much faster rate than in other waters. As a result it must be concluded that, however effective the effort has been, we still lose more than we win. Thus, despite bright spots and the growth of understanding and the ability to control, the general quality of the waters of our estuaries and coastal waters taken as a whole is worsening—at a slower rate in comparison with the growth of populations and industry than 20 years ago—but still worsening.

The agencies, institutions, and persons who have been involved in the evolution of water quality criteria and standards deserve credit. American estuaries and coastal waters are in better shape than they otherwise would be. But all concerned must realize that additional efforts are necessary before we can prevent or reverse the processes of degradation as effectively as we must.

What Must Be Done?

Several shortcomings in ability to understand and to devise and bring about effective systems for controlling the quality of estuaries and coastal waters have been identified and described above. What must be done to reduce or eliminate them?

IMPROVEMENT OF RESEARCH AND MANAGEMENT

The need for additional knowledge of the estuarine environments and organisms in question and the forces that act upon, and especially against them, is clear. So is the necessity for improved management technology and organization. Additional financial support for research and development and for management applied in the right place is clearly required. It is beyond the scope of this essay to indicate in greater detail or more specifically where the needs for research and management are. It can be said, however, that water quality criteria for estuaries and coastal waters and for dependent biota and uses must be improved! To do so, additional effort at research and engineering development is necessary. As noted above, noteworthy effort was devoted by the National Technical Advisory Committee (USDI, 1968b), the NAS-NAE group (NAS-NAE, 1973) in "The Blue Book," and by the EPA Water Quality Group (EPA, 1973) in reviewing research and engineering needs and those publications should be consulted for details. Most of the needs identified in the excellent document, "Waste Management Concepts for the Coastal Zone: Requirements for Research and Investigation" (NAS-NRC, 1970) remain unmet. It, too, provides a well-developed guide to scientific and engineering requirements for all phases of waste-management related water quality work, establishment of criteria and standards, treatment, monitoring, and other aspects of management, technology, and operations. If the research and engineering needs described in these and other recent papers are carried out rapidly, management will improve soon. If they are not—it will be later! The same applies to improvements on a) organization for management, b) criteria and standards, c) waste treatment techniques, d) system design engineering, and operation, and e) monitoring!

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SEVEN WAYS TO OBLITERATION: FACTORS OF ESTUARINE DEGRADATION

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ABSTRACT

The most significant factor contributing to the degradation of our estuaries is our failure to treat an estuary as a natural system, rather than as a convenience serving man's many and conflicting purposes. This attitude is exacerbated by lack of competence on the part of consultants called upon to predict the results of interfering with natural processes they do not understand in the first place. When this is combined with notions of cost-benefit analysis and trade-offs that justify to ourselves the addition of deleterious substances and chemicals, alteration of temperature and sediment regimes, and spillage of oil, the synergistic action may accelerate the demise of an estuary.

INTRODUCTION

Estuaries have been a major factor in the development of civilization and man's institutions. As sheltered environments for the establishment of commerce and, for the most part, pleasing sites for settlement, estuaries provide the environment for most of the great cities of the world. Yet, they are also valuable resources for food gathering, and are the site of man's first attempts to farm the sea. They are often thought of as fragile environments but, if they were, they would have been destroyed long ago. It is the daily fluctuation and the regime of environmental changes, both tidal and seasonal, that protect the life of estuaries from excessive damage, at least from moderate amounts of pollution, for the life of estuaries is adapted to, and depends on the environmental fluctuations. The same mechanisms that make estuaries excellent nutrient traps and enhance their value to life also make them pollution traps, as emphasized by W. E. Odum (1970). There can easily be too much pollution and, most dangerously, combinations of various kinds of pollution that together may have much more effect than several factors acting singly. This synergistic effect is difficult to estimate and predict.

One of the most significant sources of environmental degradation in estuaries is not usually thought of as "pollution." This is man's habit of digging up estuaries for harbors and filling their borders and sometimes middle parts, for land on which to build docks, factories, and even residences. At least 10 classes of polluting materials are discharged into estuaries and coastal waters; some of these are sewage, heavy metals, organochlorine compounds, industrial effluents of all kinds, cooling water, oil, radioactive material, and inert dumped material from estuaries. Many of these can be treated together, e.g., chemical wastes of various kinds, although we do not understand the effects of many of them. There is also the danger that we may synthesize some extremely deleterious substance whose action will become apparent before we realize that we should never have produced it in the first place.

In this context, it is useful to consider some statements from a British report on estuarine pollution:

> In considering pollution in estuaries and coastal waters, we frequently met the assumption that pollution is not a hazard unless it directly endangers human health. We therefore emphasize that dangers to other forms of life may be no less serious. For example, if it were ever to become the case that a pollutant which inhibited the capacity of microorganisms in the sea to convert carbon dioxide to oxygen, or to break down organic matter, became widespread, this could be a menace. Concern for the eventual impact on man of the ecological cycle which ultimately sustains life is sometimes misinformed, but this concern is not mere sentimentality.

> A great deal of pollution ends in the sea. Some of it is discharged through sewers directly into tidal waters; some reaches the sea through rivers. Some is carried into the air and brought down to the sea with rain; and some, including some very toxic wastes, is dumped in containers from ships. The sea is a powerful and effective scavenger of many pollutants, but recently biologists have become apprehensive about its capacity to deal indefinitely with the waste materials being put into it. There has already been enough degradation of the environment to justify this apprehension, notably in enclosed seas like the Baltic and the Mediterranean, which have very little tidal rise and fall.

> Two attitudes to the problems of pollution in estuaries now confront the public. Contamination is without any doubt taking place and some estuaries are, by general consent, highly objectionable. Impressive quantities of offensive and, in some cases, potentially dangerous substances, are being put into them and out into the sea. Evidence is available to show that these discharges may damage or destroy shellfish, birds, and fish. The immediate emotional reaction is to urge that this contamination should be stopped and stopped at once, before it is too late to reverse the process of destruction.
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> The opposing attitude is to play down the harm that is being caused and to point out, with every justification, that the discharge of sewage and industrial effluent into the estuaries reduce the costs of industry by a considerable amount. Those who hold this attitude point out correctly that to eliminate entirely these discharges would throw a heavy burden on certain of the industries concerned and generally on the local community, sufficient in some cases to cause some enterprises to be abandoned and people to be thrown out of work. Simultaneously, they argue that the tangible benefits to be gained, which can actually be costed, are minimal, amounting to little more than what would be saved by reducing damage to inshore fisheries. They claim that no damage to human health has resulted from these discharges nor has any long-term danger been proved to exist. Granted that many people are offended by the squalid condition of some estuaries; that does not justify putting local government and industry to vast cost to remove the offence.
>
> The Commission's conclusion is that the truth lies somewhere between these two sets of views. However desirable it would be to remove contamination from estuaries, there is a practical limit to the burden which should be placed on the community to achieve this aim. This limit can be defined as the point beyond which the marginal cost of abating pollution exceeds the marginal cost of the damage being done by pollution. But the inputs for this sort of calculation are rarely at hand; so in practice, arbitrary constraints have to be put on the amount of pollution. This does not only mean the tangible measurable damage such as the loss of fishery production, but includes any loss of welfare that the community may suffer as a result of the pollution. In addition, it may be some time, even years, before the damage caused by certain forms of pollution becomes apparent.
>
> (Royal Commission on Environmental Pollution, H.M.S.O., 1972.)

This rational view of the situation, as the commission concedes, constitutes an attitude of trade-off, of potential sacrifice of life or environment that can be averted only by "arbitrary constraints." Too often, from the environmentalist point of view, constraints are relaxed in favor of the short-term advantage to man. Without clearly realizing the implication of this attitude, we are treating our fellow passengers on this planet, and the environment that supports us all, as secondary in importance to our own desires and as potential nuisances that get in our way.

ECOLOGICAL INEPTITUDE

One of the greatest endangering factors which contributes less to direct degradation of estuaries than to inadequate protection measures and improper restoration recommendations is a peculiar form of half-ignorance or lack of competence on the part of the consultants and administrating officials. This deficiency usually takes the form of oversimplified statement of ecological theory and a resulting doctrinaire approach to such matters as food chains or webs, viewing diversity index as a magic number for administrative purposes. The uninformed espouse the mistaken notion that because sea and estuarine organisms produce so many eggs and larvae that a loss of 99 percent is part of the course of nature, another small percent of loss of survivors can do no harm. Inadequate understanding of ecology is not peculiar to those involved with estuaries, but the estuarine situation is beset with many more pitfalls for unwary and inadequate ecologists than terrestrial and freshwater environments.

One would hope that such a statement as the following, made in behalf of releasing pollution in a bay instead of into the ocean, is exceptional, but similar gems from the soft paper literature suggest otherwise:

> More important than the argument of plant reliability because it deals with a false concept, is the argument of fragile ecosystem populations. Biologists recognize that a population that has a high diversity is more shock-resistant than one that has low species diversity. No matter what the shock that occurs to a highly diverse population, there is some species within that population that is capable of dealing with that shock. There is a great deal of give and take in a highly complex environment such as that found in the bay. The bay is, in comparison, a more diverse ecosystem than that of the open ocean, particularly in the case of such a limited aspect of the ocean as the near shore environment off the Samoa Peninsula. Indeed, environmentally, we must consider that the bay is more amenable to transient plant operation disruptions than is the open ocean. It is on this particular error that the whole policy failure of the State Water Quality Control Board rests, as have some of the mistakes of other public agencies in the past. It is true that many estuarine systems have suffered from hypereutrophication and toxicity due to various waste discharges, including municipal effluents. None of those estuarine situations are similar to that of Humboldt Bay. Humboldt Bay does not contain the freshwater-saltwater wedge that is present in most rivermouth estuarine systems. The populations of Humboldt Bay are not subject to a daily or twice-daily shock of fresh water and salt water which limits the number of species. They are composed of hardy forms that have evolved in a system of fairly uniform temperature, salinity and density gradients subject to minor shocks of freshwater and of heavy organic loads from freshwater streams; in short, situations very much like municipal sewage treatment facility effluents. These populations have evolved to handle such minor shocks and to utilize the nutrients provided to attain high

> levels of productivity. Great diversity at the lower trophic levels of a system will be reflected in the high diversity at the upper levels of the system. It is very difficult to imagine, a system with its high productivity and high diversity at the upper levels of a system without a great deal of diversity and productivity in the lower levels of the system. One of the higher levels of a system such as that of the bay is the bird life. Birds eat the small marine animals that live on even smaller marine animals that live on the phytoplankton and the organic debris in the bay. Humboldt Bay is noted for its wildlife and especially for its waterfowl population which are highly diverse and very abundant. Birders come from all over the country to watch birds on Humboldt Bay. One of the favorite spots for watching waterfowl on Humboldt Bay is the sewage oxidation ponds of Arcata where the concentration is great and the diversity of species to be found is truly amazing. It can be easily inferred that the steps of the food web below the bird population are equally diverse, equally productive.
>
> (Challenge of Water Quality Control Plan, North Coastal Basin 1B, 1974.)

The reasoning behind this kind of inept ecology provoked Michael T. Ghiselin (1974) to remark: "Undergraduate instruction and public policy, at least, are seriously threatened by ecological orthogenesis. It is as if we were teaching medicine out of Science and Health."

This may seem harsh, but much of modern ecology is a sort of glass-bead game of rarefied abstractions manipulated with algebraic dexterity into pretty designs of many colors by young men eager to impress their masters. The Glass Bead Game of Hermann Hesse's novel was an ironic parody of scholasticism withdrawn from reality; its greatest practitioner, the Magister Ludi, died in the icy waters of an alpine lake while trying to keep up with his last student. True, he had left the sanctuary of the Glass Bead players, but too late.

The problem is not so much ignorance as it is the great demand for ecological interpretation and administration, prompted by the concern for environmental protection. Proper or adequate determination of environmental conditions and estimation of the effects of man's intervention call for more informed talent than is currently available. Mere possession of a PhD does not of itself guarantee competence or even knowledge of the subject area, and some of the suggestions made in California by W. F. Libby and Chauncey Starr at UCLA to require certification of environmental specialists or to license consulting ecologists, as engineers are licensed, could blanket in unsuitable people.

Nevertheless, we do have too many self-styled environmental consultants whose qualifications are little more than a small sum of money to pay a printer's bill for letterheads and calling cards. Significant sums of money are paid to these people for inadequate environmental impact reports. They have committed themselves to predicting the effects of a process when they do not understand the process involved. Many of the people concerned are unaware of their inadequacies, serene in the delusion that since we all live in the same environment we are all qualified to study it. The complexities of environmental studies make it difficult to set standards and qualifications for consultants and experts, however. Perhaps many of the less endowed would retire from the field if they were required to reduce their fee at least 50 percent if their environmental impact reports were disqualified as inadequate by courts or hearing bodies.

Education in the basic concepts of ecology is needed urgently. There has been too much haphazard and inadequate teaching by persons whose own grasp of ecological problems is inadequate and incomplete to begin with. Perhaps we need a concise text book for administrators and hearing officers, a guide to the interpretation of environmental impact reports. Yet, it would seem that there has been enough bad ecology in environmental assessment and impact reports to inspire the judicious skepticism necessary for interpreting inadequate work. Obviously, our greatest scarcity in this, as in so many other problems, is that rare commodity, horse-sense.

Nowhere is ecological ineptitude more clearly demonstrated than in the notions of cost-benefit and tradeoffs. An economist who suggests that we set a money value to the fish or amenity that may be destroyed by a power plant, and submit the cost-benefit ratio to a public vote, is proposing an evil and senseless procedure. This notion that we can assign money values to such diverse matters as clean water, fisheries, pleasing scenery, kilowatts, and parking lots is a recent contribution of man's hubris, especially when we make a decision on the basis of this arithmetic of apples and oranges that may extirpate other species from the scene and set irreversible ecological decay in motion; this notion is reprehensible. The idea of assigning a dollars and cents value to life—any life—can lead to the end of life on earth as it now does to the exhaustion of non-renewable resources, a mining-out of life as if it were some raw material. This approach to the problem of environmental insult assumes that the processes of nature are simple and can be safely tampered with in terms of our idiotic anthropocentricism.[1] Not only may we destroy one or several species, we may destroy gene pools by obliterating "worthless" wild relatives of cultivated

[1] Vide the graded scales of "one-ness with nature," "sense of awe," etc., in Dee, 1972.

or exploited stocks. We are—or should be—aware of the danger of this in agriculture where we have produced plant varieties incapable of adjusting themselves to change in an artificial ecological system. In fisheries also, we need reservoirs of wild genetic stocks against inevitable ecological change.

Another danger of this cost-benefit approach is that we do not know, in many cases, the key species in an ecological system and we could vote or recommend a significant species out of existence without being aware of what we have done until an irretrievable loss has occurred. To think of economics in this sense as hard and objective is a mistake, for in the field of cost-benefit analysis, economics is the squishiest and most subjective of human thought processes. It leads us to the position that in times of economic crisis we cannot afford to preserve the environment or our fellow species as we must maintain our standard of living, even if it is our standard of living that has brought us to this crisis with national resources.

In 1864, George Perkins Marsh, formerly a member of Congress from Vermont and for 20 years ambassador to Italy, published his famous book, "Man and Nature." In this book, he predicted that if mankind continued his misuse of the earth at a like rate as he had done since civilization began, the earth would become unfit for human habitation in about the same period of time. In Marsh's day, they thought that civilization was perhaps 5,000 years old. But our abuse of the earth has increased exponentially in these last 100 years so that our time has been reduced, at least an order of magnitude, from thousands to hundreds of years. At the rate we are going, our children may be the last human generation on this earth.

It is too precious a refuge from time to be subjected to the irrelevancies of ill-informed economists and incompetent ecologists; if we are to survive at all, we must drive these miserable moneychangers of cost-benefit analyses, trade-offs, and externalities out of our temple.

We talk of the "needs of man." What are they? If we put the survival of a species to a vote—and in such an election, all must vote who lead lives of quiet desperation—it is the inevitable step to the destruction of the quality of environment that man needs to continue his "standard of living." In the end, man will drink water from his sewage plants, breathe the exhaust of his factories, and reside on his own garbage heaps. Henry Thoreau, writing in his journal on April 11, 1857, foresaw it all:

> The very fishes in countless schools are driven out of a river by the improvements of the civilized man, as the pigeon and other fowls out of the air. I can hardly imagine a greater change than this produced by the influence of man in nature. Our Concord River is a dead stream in more senses than we had supposed. In what sense now does the spring ever come to the river, when the sun is not reflected from the scales of a single salmon, shad or alewife? No doubt there is some compensation for this loss, but I do not at this moment see clearly what it is. That river which the aboriginal fishes have not deserted is a more primitive and interesting river to me. It is as if some vital quality were to be lost out of a man's blood and it were to circulate more lifelessly through his veins. We are reduced to a few migrating suckers, perchance.

FILLING AND DREDGING

No factor affecting the degradation of estuaries is more permanent than filling. Once filled, for whatever purpose, an estuary is no more, and even partial filling can have serious consequences. The other side of this coin is dredging; sediments dredged to maintain channels and turning basins or to provide access to docks must be put somewhere, and often they constitute a valuable addition to waterfront real estate from the viewpoint of commerce, navigation, and industry. Indeed, it is the chief interest of harbor commissions that undesirable tidal flats be converted to useful real estate as rapidly as possible. In recent years, however, we have become aware that filling is a kind of pollution and that a tacit national policy of filling all available tidelands is in the long run not in the national interest. We have only so many estuaries, and their prime importance, both to commercial fisheries as nursing grounds for the young of various stocks and to the recreational fisherman, dictates a much more stringent policy on dredging and filling than we have had in the past. Yet, it was not quite 70 years ago that Nathaniel Southgate Shaler (1906), otherwise a man before his time in many of his environmental concerns, could write:

> There are in all the great lands vast areas of lakes, swamps, and marshes awaiting the skillful labor which has won Holland from the sea. The largest opportunity of profits is in such brave combats with the incomplete work of nature.

Shaler was not a biologist, although he was one of the moving spirits behind Agassiz's first seaside laboratory experiment at Penikese, so he perhaps could not have been expected to realize that the margins of the sea, the marshlands, and the tidal flats constitute essential parts of nature's natural system, and are not her incomplete work to be polished off for man's economic benefit.[2]

[2] Agassiz's concept for the future of Penikese as a center of practical application of studies of "fish . . . oysters, lobsters . . . ." is a startling anticipation by a 100 years of the present sea grant program. See Edward Lurie, "Nature and the American Mind" (Science History Publications, New York, 1974), pp. 59–60.

It is this aspect of dredging and filling, the destruction of the margins, or separation of them from the waters of the estuaries, that is most serious. Much of the nutrient source for the maintenance of estuarine life comes from the runoff across the marshlands and upland borders, yet often such wetlands are not protected by restrictions on dredging and filling. Referring to these areas as "wetlands," as if they were separate from the estuaries, is a mistaken classification. It is the reduction of the wetlands and of tidal access to marshes, as much as the filling itself, that has resulted in the $1.4 million estimated loss to fisheries in Boca Ciega Bay since 20 percent of its surface area has been filled, primarily for the development of small boat facilities (Taylor and Salomon, 1968). The combined factors related to the loss of fisheries value are the reduced bay volume, disturbance of bottom by dredging and bulkheading (which also separates the borders from tidal action), and consequent impaired tidal action.

There are many examples of piecemeal, bit-by-bit filling in our estuaries; it was considered the best thing to do with the shallower parts of bays, and subsequent efforts to unfill illegally filled or obliterated tidelands have not been successful. Such an area as Pony Village in North Bend, Ore., was built by filling the upper end of Pony Slough, without so much as by your leave. A large shopping mall, a motel, and several acres of paved parking space are difficult to retract.

Concern for preventing further encroachment of this kind in San Francisco Bay led to the establishment of the San Francisco Bay Conservation and Development Commission in 1965. At that time, it was realized that more than 250 square miles of the original open water surface of San Francisco Bay had been filled, and more was in prospect. One project would have cut down a large part of San Bruno Mountain to fill in areas near the San Francisco Airport. Among the possible effects of such a continued haphazard filling of San Francisco Bay could be a loss of the climatic amelioration related to the surface of San Francisco Bay itself; in short, if there were to be no bay, there would be no bay area. A public action movement led to the establishment of the commission, although the legislature was at first reluctant. The commission, consisting of representatives from state and local agencies as well as public members, has jurisdiction over filling. Unfortunately, its jurisdiction includes only the bay and harbor development, not the entire estuary system. It has undoubtedly prevented some excesses, but as the interests of the membership become more vested, it shows signs of losing some of its original missionary zeal and fire. So it is often with public bodies, no matter how high-minded.

Unless, of course, they are harbor commissions. These bodies are always concerned with developing ports and harbors. Quite often, the development is related to the personal interests of some of the members, but it would be impossible to form such a body otherwise. In some parts of the country, it would appear that there is not enough disinterested and knowledgeable talent to staff the commissions, yet these commissions often have powers that are greater than those of any other local bodies, since they are responsible for state lands. Some years ago, the Harbor Commission for Bolinas Lagoon, a small marine embayment just north of San Francisco, planned extensive marina development which would have completely changed the character of the lagoon. As a result of public outcry, the Harbor Commission itself was abolished in 1969. This ought to happen to more small harbor commissions which forget that they are in charge of a living environment, not potential marina property.

DIVERSION

Since an estuary is a region mixing fresh waters of terrestrial origin and saline water from the sea, it follows that diversion of fresh water in significant quantities will change the character of the estuary system involved. Diversion of all the fresh water would turn an estuary into a marine lagoon; in such an event, the productivity base of the system would depend entirely upon the neighboring sea and the vagaries of tidal exchange. Such systems, as exemplified by the saline lagoons of south Texas, may fluctuate and be less dependable in their fisheries resources than a well-balanced estuarine system. Yet, major diversions have been proposed for the Texas bays and, while these may be pipe dreams of engineers, one cannot forget that such ideas have been proposed and that, in one case, are well on the way to fulfillment unless there is a drastic change in water policy.

This is, of course, the diversion of water from northern California to putative agricultural lands of the San Joaquin Valley and the megalopolis of Los Angeles. The diversion is to be accomplished by an elaborate bypass system, called the Peripheral Canal, around the delta (confluence) of the Sacramento-San Joaquin Rivers. The diversion scheme has proceeded in the absence of sound environmental or hydrological information; it is considered impossible, for example, to compute the volume of water that flows out of the delta into San Francisco Bay, because of the complex nature of channels, sloughs, and streams. Estimates of diversion of water to Los Angeles that would leave perhaps about 50 percent of the net outflow required to maintain water quality and protect fishlife aroused alarm and stimulated lengthy hearings before the California Water Resources Control Board in 1969–1970 The upshot of these hearings was Decision 1379 (1971), which recommended substantial increases in flow from the delta in low water periods, which would reduce the diversion to the southlands desired by the California Department of Water Resources by perhaps 0 9 million acre feet. Decision 1379, which in effect recognized ecological water rights, has been considered a landmark decision, but it has been bitterly opposed by the diversion interests and is under appeal In the meanwhile, the Department of Water Resources has issued its environmental impact report on the Peripheral Canal, contending that all will be well if water is released in a sort of bleeding action at various places along the canal into the delta system

In all, the EIR for the Peripheral Canal has not satisfied everyone and, most conspicuously, there is not an adequate assessment of the impact of the vast quantities of electrical energy needed to operate the pumping system upon the economics of the diversion and other energy needs

There are other ways to accomplish diversion of water from an estuary besides turning the water into a ditch to be carried away Our concern for protecting estuaries from temperature increases from cooling waters may result in practices that could in the long run achieve the same effect by reducing the volume of river flow Proposals for power generation in the Susquehanna Valley, for example, could lose large volumes of water by evaporation in closed circuit cooling systems and towers, perhaps amounting to a third of the low-water flow of the Susquehanna, one of the major tributaries of the Chesapeake Bay (Olson, 1974)

Such a possibility suggests that more serious consideration be given to reducing evaporation loss in cooling systems; certainly, the great battery of cooling fountains at the Pacific Gas and Electric cooling ponds at Pittsburgh function admirably as evaporators. Large numbers of such cooling systems, combined with the flow reduction for the California waterworks, might increase the loss of water to the system by unacceptable amounts.

Not long ago, it was suggested in Oregon that, because of the scarcity of fresh water in many coastal regions during dry years, entire streams be diverted from above tidewater during the summer months. It was thought by whoever made this suggestion that the estuaries were not being used by fish and other life during the summer months, so that there would be no serious effect on the estuaries!

One of the serious aspects of diversion of water is the reduction of the natural sediment load of streams flowing into bays and estuaries As brought out in the hearings about the diversion of water from the delta in San Francisco Bay, this reduction could have a serious effect on primary productivity and the ability of the estuary to handle pollutants, since fine sediment particles protect the waters from excessive sunlight and function as scavengers by bringing down heavy metals when they flocculate on reaching the saltwater part of the estuary.

In this context, it is not encouraging to find that detailed consideration of altered sedimentation processes has been omitted from the environmental impact report on the Peripheral Canal prepared by the California Department of Water Resources One is reminded that the excessive sediment loads in San Francisco Bay from hydraulic mining were not stopped because they were shoaling the bay and altering the tidal prism as a consequence (Gilbert, 1917), but because the mining debris was destroying farmlands

A point often forgotten about natural sediment loads in our estuaries is that the heaviest occur during the runoff season, when river temperatures are lowest A similar heavy sediment discharge or accelerated erosion in summer, from construction activities or farming is deleterious to the life of an estuary

CALEFACTION

Calefaction, the process of making things a bit warmer, was dredged from the dictionary by Daniel Merriman a few years ago (1970a) The idea implicit in Merriman's usage was that a little calefaction did no serious harm, the increases in temperatures associated with the power plant on the Connecticut River that was his principal concern were not causing any significant change in the sequence of events, except that some catfish were not doing well But the Connecticut River in the region of the power plant in question is subject to tidal action and the thermal plume did not really calefy the river So, in the sense of increasing the temperature of the environment, there was not any real calefaction at all, and the observed effects could be just as reasonably attributed to entrainment, the drawing in of water through the plant, and to scour from the steady effluent current from the discharge outfall of the plant

Nevertheless, calefaction is a real concern and we are aware of situations where temperature increases from the use of environmental water as a coolant may reach significant values. Furthermore, while the present scale of operations may not have serious effects on open coasts, our increasing reliance upon coastal water to cool down the exponentially expanding power-generating installations suggests that the time is not far off when we may anticipate significant changes in nearshore temperatures. A few massive power plants here and there, releasing warmer water into a small region near the outfall may have no real effect except upon the organisms ground to bits within the plumbing, but arrays of ever larger generating plants pumping significant percentages of the nearshore currents of an open coast or of an estuary into their condensers and release of the warm water into the environment may cause a serious alteration of the environment.

It was suggested, for example, that our engineering capacity might make it possible for us to construct perhaps 4,000 nuclear parks along the shore to utilize coastal water for cooling purposes (Weinberg and Hammond, 1970). A series of power plants on that scale, designed to meet all our exaggerated demands for energy by supplying power to 20 billion people at our present rate of consumption, would undoubtedly change the character of coastal waters. It would also seem that such a bulk of people would of itself increase the temperature of the earth. One would like to think that the authors had a satirical intent and did not really believe their own estimates, since they gave no serious thought to possible effects on nearshore circulation patterns or plankton populations. Some lip service is given to ecological considerations in a brochure titled "Siting Considerations for Offshore Nuclear Power Plants" (Dames and Moore Engineering Bulletin 42, 1973); it is stated on p. 31 that "part of the overall objective is to see whether the site is sufficiently decoupled ecologically from . . . associated estuarine systems."

Temperature is a relative measure of the amount of heat, and heat is the energy of molecules in motion. The lowest possible temperature would be that of the situation in which there is no molecular motion, or $-273.15°C$ ($0°K$); at the other extreme, the temperature of the sun is several thousand degrees. Temperatures in the sea range from -2.0 or $-1.8°$ in the deepest trenches and near surface Antarctic waters to over 40° at the surface in semi-enclosed tropic waters such as the Red Sea. The average temperature of all water masses of the world ocean is about 3.9°C.

No form of life that we know can withstand the extremes of absolute zero or the heat of the sun, and the range of temperature encountered in the sea and estuaries is but a small fraction of the range of conditions that occur on land. Very few organisms are adapted to survive even a small part of the total range of temperatures occurring in the sea. Many of the organisms of the Antarctic and abyssal seas experience temperatures within the narrow range of about -2.0 to $+1.5°C$ or so, whereas species of shallow tropical waters may live within the range between 20 and 30°C. Most organisms appear to be able to withstand short period extremes of temperature; such tolerance depends upon other factors in combination with the temperature rise or fall, such as oxygenation, or reduction of internal temperature by evaporation in intertidal species. Many organisms can adjust themselves to long-term altered temperatures, within certain limits; such adjustment is called acclimation. Many others are adapted to regular variations or seasonal temperature cycles. Others, we suspect, meet the temperature variations in nature, especially those associated with changes in strength or position of currents, turbulence, and internal waves by producing an excess of reproductive stages, most of which are sacrificed to environmental vicissitudes. Therefore, we must consider the temperature regimes of each situation somewhat differently.

With respect to the attrition of reproductive stages, it cannot be assumed that because 99 percent of the young produced by a species are lost, we may safely levy upon the remaining 1 percent. For many organisms, the cleavage stages may be most sensitive to temperature, and later stages progressively less so, but the vulnerability of all stages suggests that exposure to artificially high temperatures should be as short as possible. And, while the adult may be the least sensitive, it must produce this vast excess of young to ensure at least one adult survivor for the next generation. A single reproducing adult (or a pair) may not be enough, conversely, to establish a new population, as demonstrated by the many failures to establish exotic species.

Some critical mass of reproducing adults seems necessary to establish populations in new waters. Thus, at both ends of the logarithmic curve of population, matters are difficult for survival in nature; whatever the optimum may be, the sea is not a benign and undemanding environment, but quite the reverse.

It would be impossible to summarize the extensive literature on studies of the effects of temperature upon organisms in anything less than a large book, yet this work taken together leaves something to be desired when we try to understand the actual relations of temperature to organisms in the environment. Environmental events usually have not been synchronized with laboratory tests and seldom have experiments taken into consideration the fluctuating regimes of the actual environment. As with many other factors, laboratory tests are simplifications or abstractions which may give us clues to how or why things happen in nature, but fail to explain what may really be happening.

Now, to the sometimes irrelevant data of experimental physiology, we have added the even less relevant data of environmental impact studies. Too often, such studies are beside the point and leave the basic problem untouched. For example, an investigation of the possible effects of a warm water effluent on shallow water organisms presents temperature measurements of the uppermost surface layer taken by a distant infrared sensor, and lists of species, numbers, and size classes of invertebrates living from several centimeters to perhaps two or three meters below this measured layer, or within the sediment still further removed from the surface layer. Values are correlated and regression lines drawn, indicating as might be expected that there is no relationship between surface effluent temperatures and the biota beneath. Unfortunately, the conclusion is then offered that the altered temperatures have no effect on the biota, a conclusion that cannot be substantiated by the data offered (Adams, Price and Clogston, 1974).

Such misleading interpretations of inadequate data are far too common and there is little to choose between this quasi-scientific approach, often invested with the trappings of quantitative ecology, and the public relations interpretation that the warm water effluent outfall of a power plant enhances fish life. The latter approach is based on the observation that more fish may be caught there than in other parts of the nearby environment. However, this rationale fails to make it clear that perhaps the power plant site may be the only place at which fishing is possible along that part of the waterfront; nor does it point out that nowadays such fishing is welcomed, to promote the idea that fish are thriving there or that a parking lot for company employees is open to visitors who desire to fish during off hours.

Much of the literature of physiological responses to temperature by fishes and invertebrates is difficult to interpret without adding this kind of logic to the confusion. Too often, experimental data is based on restrictive conditions not typical of what is actually happening in the environment. A lethal temperature for sea urchins may be demonstrated in the laboratory that is below the actual conditions under which the species may survive at low tide in nature, because the cooling of the animal by evaporation and its access to abundant oxygen are factors eliminated from the experimental protocol. Even more significantly, the range of variation, the rebound from very warm conditions at low tide to the daily immersion in water many degrees cooler, is not taken into consideration. The situation is extreme in estuarine and intertidal organisms; many of these, however, are the organisms most likely to be within range of a warm water plume from a power plant.

It must be remembered that while there may be no direct relation between a warm surface temperature and the organisms only a few centimeters below, the surface layer is one of the most biologically active regions of the sea, and that what happens in this interface between sea and air ultimately affects all life in the sea (MacIntyre, 1974). Thus, while some fish or clam or other invertebrate may well withstand the increased temperature of a power plant and perhaps survive a trip through the condenser tubes, the real impact on the environment may be of a different order entirely, subtle, not easily measured, and not perceptible for perhaps several years. Here in the active surface layer is the *mare incognitum* of calefaction. Tentative evidence suggests that there may be danger of interfering with the basic productivity of the system, which would be far more serious than Merriman's "marasmus of catfish."

The literature on thermal relationships of organisms is a tide that shows no sign of ebbing. Coutant and Goodyear (1972) listed 394 references, most of them published during 1971. The application of much of the experimental work to practical problems of thermal alteration is debatable, as the authors emphasize:

> Determining the tolerance of aquatic organisms to temperature extremes, both upper and lower, is a common experimental goal which has been given new relevance by thermal discharges from the electric power generating industry. In principle, the data obtained should have predictive utility for managing thermal discharges for minimum ecological impact. . . . Critical study of the reports published largely in 1971, however, indicated that any predictive utility is severely hampered by the plethora of experimental methods employed in the laboratory and the wide divergence of the quality of field observations. . . . Anyone wishing to use tolerance data from most of these reports must certainly read in its entirety the experimenter's paper in hopes of finding a rationale for that particular methodology and the particular limitations of results.
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> (Coutant and Goodyear, 1972, p. 1263.)

The barrage of impact studies, pre-operational surveys of plant sites, and luncheon speeches circulated in mimeographed form that comprise such a large part of the soft paper literature suffer similar defects without even the purgative of editorial review.

Natural temperature regimes, the seasonal variation from cold in winter to warm in summer, are not consistent and undeviating from year to year, although much of the discussion of thermal alteration of the environment by human activity would imply that the only change in the environment is that possibly induced by human agency As with the terrestrial climate, however, temperature changes in the sea vary in their onset throughout the seasons, and often in unexpected ways which may be related to the global climatic fluctuations. Variations in temperature of the seas are often in the order of two or three degrees above or below the yearly average There appears to be some relation between such small magnitude temperature changes and the success of major fisheries stocks; the catastrophic decline in the abundance of the California sardine may have been related to changing temperatures in the 1940's along the Pacific coast of North America We do know, for example, that the eggs of the California sardine hatch most rapidly at 17°C and that a decrease of 1° adds six hours to the hatching time, so that at 15° the hatching period is increased from 54 to 77 hours It was estimated that a 3° decrease in temperature (and since the sardine egg floats at the surface, these are surface conditions) during the period of hatching and development of the larvae could decrease survival of the eggs by as much as 10 times

The world's climate may be in a warming phase, according to some meteorologists, whereas others with equal reasonableness have announced that the present warm interglacial period has about run its course and within a few hundred years (or millenia) the glaciers will be back The prospect of climatic change induced by man's industrial activities is also seriously considered by such authorities A number of proposals for tampering with the earth's thermostatic system, the ocean—including the rearrangement of the freshwater supply of North America, Africa, and Siberia by massive impoundments and canals—could have unanticipated effects on coastal and estuarine environments of the regions concerned, since the freshwater contribution would be severely reduced.

Proposals for tampering with the regime of the sea itself include the Bering Strait Dam, which would, it is hoped, result in warming waters of the Arctic Ocean, although some oceanographic opinion suggests that such an effect would be masked or negated by the natural variations of the Atlantic water flowing into the Arctic Basin.

In view of the natural fluctuations in the sea and possible major interrelations between events in the northern and southern Pacific Ocean masses in particular and the climatic variations within historic times in many parts of the ocean, one may well ask why we should be concerned at all over a little calefaction. The problem is that our meddling with the climate, inadvertent or deliberate, may result in temperature anomalies that are out of phase with environmental events This is essentially what happened in England where an attempt was made to domesticate the eastern American hard shell clam (quahog, *Mercenaria mercenaria*) in the warm effluent of a power plant adjacent to a sewage treatment works Here was a situation where everything seemed right: a source of warm water, a source of carbon dioxide, and nutrients for plant growth. But the larvae of the clams could not be held in place, and were produced out of phase with the natural cycle of the adjacent sea.

It should be emphasized also that maintenance of stable temperatures in such situations may depend on the operating conditions in the power plant, that such conditions depend on the demands of industries and municipalities, and that these demands may at times conflict with the seasonal requirements During the summer, for example, power demand may be reduced and the schedule of plant operation reduced, with a resultant drop in delta T at the outfall, on a cold upwelling coast such as Oregon, where upwelling is most intense in midsummer, it might prove uneconomical to operate in accord with the temperature demands of the local shrimp or mussel farm

Or, for that matter, to maintain artificially altered local environmental conditions for the benefit of the acclimated fauna This is illustrated by an episode in the Chesapeake Bay where fish, attracted to a warm water effluent, were killed by cold water during a shutdown of the power plant in winter

Our present knowledge of the subtle and intricate relations of life within the environmental ranges of temperatures in which they have evolved and become adapted is inadequate to reassure us that even a little calefaction can do no harm In his effort to reassure us that the warm water effluent of the Haddam's Neck power plant is doing no real harm to the environment or its biota, Merriman (1970b) nevertheless suggested that the present limits were about as far as we should go Certainly we can exceed biological limits with very little increase in temperature in the tropics where the marine biota is already living near its upper limits of tolerance Who knows what the effects of warming the Arctic might be upon slow-growing organisms adapted to low temperatures? Inevitably, artificial calefaction will be subject to fluctuations because of the added perturbations and off-and-on phases associated with operation of the associated machinery. The limits of calefaction may be much lower than we think.

From the viewpoint of a naturalist, it may not be only the amount of temperature change we may bring about, but the rate of such changes which may have unforeseen consequences on the biota of our coastal seas and estuaries. So much of our data is tentative or applicable only to individual specimens or species that we must be conservative about the effects of potential calefaction upon communities or the interactions of animals in nature. We are told that "we do not have the time to wait" for such understanding, which is the same as saying "we do not have the time to consider the consequences of our action." Such anthropocentric arrogance! Do we really have the authority to tell the rest of organic life that their future is contingent upon our immediate understanding of what our needs may be?

It must be reemphasized that, with respect to tampering with the phenomena of nature, the viewpoint of the naturalist is profoundly different from that of the engineer. The engineer approaches such problems with an attitude of complacence, or with the assumption that if what we do is bad, we can change or stop what we are doing. The naturalist knows that life is not a reversible process—an environment to some extent, and a species absolutely, once destroyed, cannot be restored. A "try it and see" attitude about any pollutant inimical to life processes is profoundly dangerous. Calefaction cannot be considered an exception, even where it might seem most permissible, in our coastal waters. The naturalist can only view changes in temperature as he does all pollutants, as potentially damaging unless proven otherwise.

SEWAGE: ORGANIC POLLUTION

Pollution of rivers and estuaries by man's effluvia has been with us since the establishment of cities, but wholesale release of wastes in liquid form as domestic sewage is a comparatively new environmental factor. To the extent that sewage consists of readily biodegradable or natural substances, its effects may not be irreversible and, in time, estuary systems heavily polluted by sewage may recover. Recovery is apparently now happening in the Thames River, which, a century ago, was a foul-smelling distressing mess, but to which fish are now returning. This is not to say that we can continue to pollute estuaries indefinitely with sewage, under the notion that, once we stop, all will be well. Excess production of blooms and large biomasses of not-altogether, desirable species may result in the

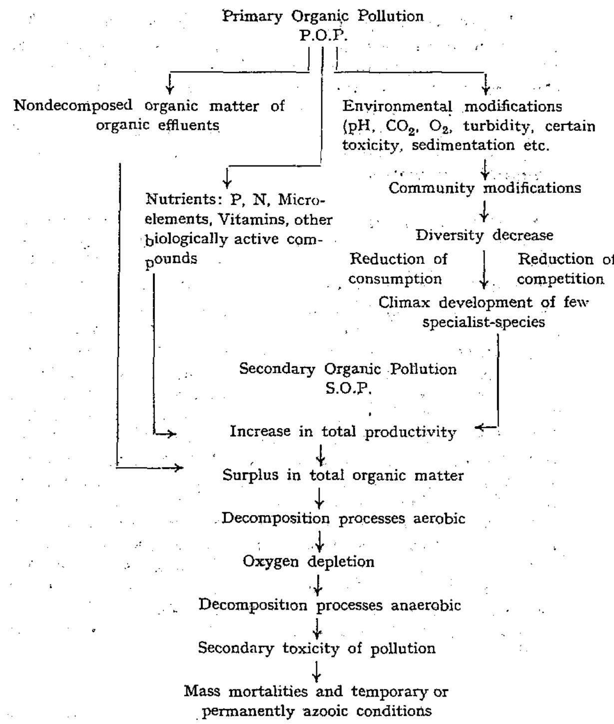

FIGURE 1.—Schematic presentation of processes of organic pollution and its consequences in marine environment (Stirn, 1973).

extirpation or elimination of more valuable species to such an extent that their return to a revitalized estuary may be long delayed or impossible (Figure 1). Bascom (1974) has suggested that the ocean is the best place for our effluents, but it is still too early to be certain that massive releases of excess material will be processed for us by the ocean without some damage or alteration of the natural system.

In any event, we have come to the position that estuaries are not the best place for untreated sewage outfalls. There seems to be no deleterious effect of disposing unprocessed human sewage in the cold waters of Cook Inlet, Alaska; at least, the major factor in the inlet is tidal exchange, rather than biological processes within the system. However, the capacity of the inlet is said to be finite, and not adequately understood (Murphy, 1972).

It is often pointed out that we may be wasting valuable material by open ocean disposal and that excess discharges into bays must be prevented. A recent statement of the case for use of our wastes in mariculture is that of Joze Stirn (1973):

> In my opinion, a theoretically ideal solution for sewage disposal would follow these requirements: effluents should not have a destructive influence upon marine ecosystems, which happens as a rule in quite large territories encircling underwater outfalls, and they

> should not accelerate uncontrolled and useless eutrophication, which is also the case whether the effluents have been previously treated or not. This leads to undesirable changes, including aesthetical and sanitary ones, particularly and in a drastic way, in shallow coastal waters, i.e., in these parts to which the recreational activities and with them the important growth of the national economies as well are focused.
>
> Sewage-born nutrients, including biologically active organic compounds, should be saved and returned to bioproductive processes in a way which could enable their utilization as food for the growing human population . . . . an optimal solution might be found within a potential possibility of developing a combined treatment-mariculture technology. There is of course no ambition of using this idea as a universal suggestion, which it cannot be, among others, because of a particular reason: for every coastal mariculture, an adequate geomorphological formation (bay, fjord, estuary, abolished salinas, lagoon) has to exist, available for this purpose, and out of competition of space with more rentable industries. Considering the Mediterranean or similar areas (where the mariculture has to be promoted anyway), we are dealing from this point of view with an enormous number of adequate geomorphological formations, located as a rule just in the economically passive (excluding tourism) territories, many of them desert, whether real ones in the south or karstic barelands in the north and in the east.

Such direct use of organic wastes in maricultural projects will not of course take care of all the organic wastes generated by man and processed in sewage plants, and use of solid wastes on land has been and should continue to be a significant application of this valuable resource. Nevertheless, we have not progressed far since the extravagant waste of this valuable resource in France was so eloquently denounced by Victor Hugo in "Les Miserables:"[3]

> Paris throws five millions a year into the sea. And this without metaphor. How, and in what manner? day and night. With what object? without any object. With what thought? without thinking of it. For what return? for nothing. By means of what organ? by means of its intestine. What is its intestine? its sewer.
>
> We fit out convoys of ships, at great expense, to gather up at the south pole the droppings of petrels and penguins, and the incalculable element of wealth which we have under our own hand, we send to the sea. All the human and animal manure which the world loses, restored to the land instead of being thrown into the water, would suffice to nourish the world.

Sea disposal of recyclable organic wastes is not the extravagance that Hugo supposed, however, for we do owe the sea some of its substance and the steady drain of protein from the sea in our great fisheries should be repaid. But it is not economical to take it back to Peru, so we dump it into the sea at New York, Los Angeles, and other great maritime centers of population. A far greater waste would be to discharge purified fresh water into the sea, yet some water quality requirements have approached this extravagant ultimate.

ALL OTHER CHEMICALS

We throw everything soluble (and often the insoluble substances as well) into our streams and estuaries; our rivers may "wind somewhere safe to sea," but with a burden of substances alien to the environment as man knew it barely 200 years ago. The era of affluence and effluence is still in its beginning and, while it may not last much longer even in the terms of human history, the potential damage from the complex of chemical wastes we are producing is incalculable. Even in the terms of a human lifespan, the effects of a particular substance are difficult to assess, because it may take 25 or 30 years for a cancerous condition related to some substance to develop, or at least to be noticed. We do not know what we are doing, yet if everything does not turn up dead because of some chemical we discard into the estuary, we seem to think we can continue to dump it.

There seems little point in discussing all the possible kinds of chemicals individually (as opposed to natural or quasi-natural organic substances that result from the excretion or death of organisms); they include the unusable or economically unretrievable wastes of our advanced and complicated chemical industry as it operates along our watercourses—from pulp mills to petrochemicals from the growing plastics industry. This last industry, it might be noted, is based on the wastage of resources in all sorts of plastic accessories and containers, and evidently assumes free disposal of all this junk to the environment. It may not be long before the most common object dredged from our estuaries will be the plastic ballpoint and felt-tip pen cases that are produced by the millions. It is now impossible to walk along an ocean shore without finding a few on any given day. I have picked up disposable syringes and discarded ballpoints at Punta Espinosa in the Galapagos; discarded, I am sorry to say, by visiting scientists.

Toward the closing years of World War II, we released four categories of pollutants into the environment which we now realize as deleterious to life: radioactive isotopes from military and industrial uses, antibiotics (sulfa drugs and others), insecticides (such as DDT), and detergents. To these Four Horsemen of the Ecological Apocalypse, we have since added a Fifth, the effluvia of our plastics industry, the polychlorinated biphenols, chlorides, and all the solid bits and pieces that are now turning

[3] "Les Miserables" was published in 1862. The two paragraphs quoted are a small part of the panegyric to the sewers of Paris, from Jean Valjean, the last book of the novel.

up in the surface layers of the ocean, far from land. It is difficult to decide which substance may produce new and greater dangers to aquatic life. Many of them persist for years, and may surface in unexpected places with unanticipated effects. It is not easy to estimate the significance of potential pollutants in the sea and estuaries, as indicated by a recent study conducted by the National Academy of Science (Goldberg, et al., 1974).

Always remember that we develop pesticides and herbicides to kill things. We apply tons of them to farmlands, gardens, and marshlands every year; by 1972, 390 or more kinds of chemicals were used to kill or control unwanted organisms. It says something for the ecological viability of many of these pests that we must continue to use noxious substances to get them out of our way; at the same time, we risk destruction of other forms of life which we may not be able to afford to lose from our environment in the long run. As for the pests, their ecological viability depends primarily on the ideal conditions we have set up for them, especially in our vast areas of single crop agriculture. Conversely, we must also add fertilizers to keep the crops growing, and if we do not continue this double jeopardy of fertilizers and biocides, the whole artificial system collapses into the diversified but less immediately productive system of undeveloped or preindustrialized agriculture.

As we continue to keep our chemists busy developing new and more deadly substances, the danger that we may develop some universal biocide increases. Insecticides developed specifically to kill arthropods may in time kill off many arthropods in estuaries and seas; some herbicides may sterilize a stream of all arthropod life. Yet, too often we find out about the effects of these substances after they have been tried out, not before. It is admittedly difficult to decide what effect, if any, new substances being synthesized and put to use may have; for one thing, many industries keep their processes private and it is difficult to determine what some proprietary substance is, or what processes may produce dangerous chemicals. The long generation time of some diseases in man and of the induction of ecological imbalances also make estimation of the effect of a newly-synthesized chemical difficult.

In a general way, the chemical pollution of estuaries consists of the following kinds of substances:

1. *Heavy metals*, e.g., mercury, zinc, copper, cadmium, primarily from industry, but in some cases, as probably in San Francisco Bay, much of the mercury detected in sediments may come from drainages through cinnabar-rich deposits in the region. An increasing source of heavy metals is from malfunctioning heat exchangers; in one recent incident, enough copper was released from the tubing of the condenser of the nuclear power plant being constructed at Diablo Canyon on the California coast to kill large numbers of abalone (San Francisco Chronicle, January 24, 1975).

2. *Mill wastes.* The effluents of pulp mills consist of sulfate or sulfite liquors, indigestible wood particles (lignin) and other substances; often, the exact composition of the wastes is considered a proprietary secret, as it would betray the nature of the process. Steel mills may release cyanides, phenols and ammonia.

3. *Refinery effluent* usually consists of volatile hydrocarbons; crude oil is in a special category and may produce a catastrophic environmental mess in confined waters, although direct long-term damage is not easily measured. Some fractions such as diesel or heating oil act differently from the rest, moving into the bottom sediment and persisting in a condition hazardous to benthic life for many years.

4. *Pesticides, herbicides, and other agricultural runoff.* In some regions, as predicted for San Francisco Bay, there may be added the salinized agricultural runoff water from irrigated fields. A new addition to synthetic organics are artificial pheromones, substances that act like hormones and upset the natural sexual cycles of insects. Some of these may be dangerous to marine anthropods in very low concentrations, but they are only now being investigated.

5. *Chemical processing plant wastes.* Ours is an era of chemistry and the kinds of pollutants from our vast and complex industry are legion. They include acids, alcohols, all sorts of inorganic salts, and chemically inert materials that may interfere with filter feeding organisms. (The effect of taconite processing wastes could be very different from that in Lake Superior, for example.) Many chemicals are neutralized or rendered inert by interaction with seawater in more saline estuary conditions; others may become dangerous to life.

6. *Litter.* Bits of flotsam and jetsam have always been with us, but a new feature of our culture is the vast amount of material that is for the most part chemically inert, and reducible, if at all, by mechanical action. The surface of the oceans almost everywhere is littered with small pieces of plastic and the shores of estuaries are an unsightly mess of plastic receptacles, parts of toys, ballpoint pens, and sheets of plastic. Cans, bottles, and boxes degrade in time, but such things as the bridles for six packs of beverage may persist for years. None of this is pleasing to the eye and its effect on organisms, other

than physical entrapment or clogging the alimentary tract, is yet to be determined.

Obviously, it is impractical to monitor all the substances being released into the environment, especially when the presence or nature of some of them are unknown. One would like to have everyone assume, as good biologists should, that until proved harmless, a new substance should not be released in the environment for any purpose, and perhaps this is done on some other planet in some other galaxy, but not on the only planet we have.

OIL

So far, there have been few oil spills in estuaries; the spectacular Santa Barbara incident of 1969 occurred on the open coast. Fortunately, most of the spillage from the tanker collision at the mouth of San Francisco Bay on January 8, 1971, passed out of the bay, but major spill, and leakage from increased loading and unloading operations in busy ports is inevitable. Small leakages, in the order of perhaps several barrels a day, are considered a normal part of operations in an oil port, and such leakages are predicted for Port Valdez in Alaska when tankers will be loaded from the end of the Alaska pipeline. The example of what is happening in Bantry Bay on the west coast of Ireland is not reassuring. There have as yet been no adequate studies of the effects of such chronic pollution; most of our major ports have been subjected to this sort of thing for so long that no baseline is available from which to judge such effects. Port Valdez would be an ideal site for a baseline study, before the oil-loading facilities become operational.

Few harbors in North America are adequate for the massive new supertankers which may draw more than 60 feet when loaded; recently, a medium-sized (100,000 tons, dead weight) tanker was unloaded in San Francisco Bay at Richmond, but it was necessary to transfer three 15,000 tanker-loads from the large tanker before the ship could be moved to the dock. This sort of thing means more dangers from spillage with increased handling and, eventually, from an expensive fire along a commercial waterfront.

Unloading oil at refineries or pipelines is not the only source of potential pollution; many large power plants have their own oil docks, or plan to increase their facilities. For example, the Pacific Gas and Electric Company has applied for a permit from the Corps of Engineers to dredge 56,000 cubic yards from San Francisco Bay, to increase the capacity of its dock at Pittsburgh, some miles up the bay beyond Carquinez Strait. At the present time, tankers of 30,000 tons dead weight can be accommodated; the increased depth would make it possible for tankers of 70,000 tons dead weight to unload. One cannot of course afford to spill oil these days, and doubtless every precaution would be taken to prevent loss, but the public was not reassured to have the company attorney state that no expansion of dock facilities was planned for the Pittsburgh dock, at the same time the permit was being applied for. Such lack of communication within the company suggests operational difficulties could develop at the peril of the environment.

Puget Sound will be especially vulnerable to tanker accidents, because of the narrow passages to the proposed facilities near Bellingham and the density of maritime traffic. In anticipation of the potential difficulties in the region, a group of students and instructors at the University of Washington attempted to assess the problem and recommend procedures in the event of a major oil spill. The resulting document, "Oil on Puget Sound: an Interdisciplinary Study in Systems Engineering" (University of Washington Press, 1972), is a most instructive analysis of the problems, first of all of getting any accurate idea of the present magnitude of oil loss in Puget Sound and, most significantly, in revealing the lack of any coordinated plan or procedure to cope with the situation. These problems are concisely stated in the preface to this bulky contribution, and the statement can serve for other ports and estuaries in the United States as well:

> The objectives set forth at the beginning of the study were to define the oil spill problem in Puget Sound and to formulate a model for the solution of the problem. The study group discovered, as the study progressed, that identifying the sources and consequences of oil spills was a most time-consuming task. If solving a problem warrants a ten dollar reward, then definition of that problem should be worth at least one hundred dollars. At least, this was the sentiment of the group upon completion of their study. Thus, the primary efforts of the students were in collecting, analyzing, and evaluating data on Puget Sound and its related oil industry. It was only after completion of this tedious task that a meaningful solution could emerge.
>
> * * * * *
>
> For the results of this study to evolve into an effective solution to the oil spill problem, the organizations involved, and the people within them, must consent willingly to change. Nothing could be worse than blindly instituting some legislation, technique, or procedure without fully understanding or accepting the overall impact of its activation. Too often, such fragmented actions are taken to obtain short run, narrow solutions to problems without evaluating the bigger picture.
>
> Historically, plans to cope with oil spills have emerged as the aftermath of disasters, or have been formulated in a vacuum, without considering the implication or consequence of such plans. Therefore, the most important message of this report is: *The environmental preser-*

vation of the Puget Sound region requires the coördinated effort of all responsible and capable parties, whether they represent society or industry.

(Vagners et al., 1972.)

It is to be hoped, as oil becomes more expensive and scarce, that economics will force more concern and less wastage if environmental concerns remain ineffective. Public concern was increased in the Puget Sound region by a series of articles in the Seattle Post Intelligencer during the last week of October 1974, which concluded with the question of the value of Puget Sound itself—is it worth the risk of a catastrophic oil spill, or do the "benefits" of massive oil commerce offset such a loss? Senator Magnuson, running for reelection, evidently sensed the public sentiment by taking the public position that the big tankers must be kept out of the inland waters of Puget Sound.

Attention was called during this controversy to the large oil spill from the tanker Metula in the Straits of Magellan; a more recent account suggests that the results of this spill, which occurred on August 9, 1974, may persist for years (Washington Post, Feb. 19, 1975). Because of the remoteness of the area and the expense, the government of Chile has been unable to make any attempt to clean up the 18 million gallons of oil. Obviously, these vast tankers should be kept to the open sea and broad, easily navigated harbors. Our estuaries do not meet these criteria.

SUMMARY

Since this review is essentially a summary of various factors degrading estuaries, a summary seems hardly necessary. If there is any conclusion to draw from this recital of estuarine ills, it is that much of what has happened to our estuaries is the result of our obsession with managing this most valuable of interface environments from the viewpoint of some specific use desired by man, or that planning panacea, "multiple purpose." Our recognition of environmental quality, of the need for maintaining "environmental integrity," suggests that our primary concern should be to manage estuaries on their own terms, as natural environments. Such management is inhibited by ecological ignorance or misunderstanding and, especially in most large estuaries, by conflicting jurisdictions and interests, by refusal of various local governmental agencies, as well as state and federal jurisdictions, to surrender sovereignty for the good of the natural system as a whole. All the mechanical (filling, dredging, diversion) and chemical pollution of our estuaries is exacerbated by our incomplete understanding of ecological processes and the confused idea that cost-benefit ratios and trade-offs are intelligent management policies. Such concepts have no real meaning in the maintenance of natural conditions in the environment. It follows that most of our problems with estuaries (and of course with everything else) rise out of our own inadequacies and shortcomings, prompted by our anthropocentric concerns.

It is symptomatic of our present state of knowledge of estuarine management that Perkins (1974) in his text on the biology of estuaries, should devote more than 90 pages (including a list of 402 references) to biological effects of waste disposal, and six pages (with 10 references) to management.

One should not, however, stand too long at the wailing wall, but hope that we can learn to manage our estuaries without altering them for the worst. We have abundant information to help us in understanding many of our estuaries. What we need is respect for them as unique and significant environments; as I have stated in another context, we should develop an "estuarine conscience," a concern for estuaries on their own terms, not on ours, and get on with the task:

> The continued reliance upon consultants and other advisers to produce development plans, management studies, and proposals for monitoring programs are diverting funds from needed activities. The broad national policy is that estuaries must be preserved and maintained, and it is time that we began to do just that.
>
> (Hedgpeth, 1973.)

To put it more concisely, we have recognized that estuaries are places for life, not death, the places where the rivers should come safely to the sea.

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INTERACTIONS OF POLLUTANTS WITH THE USES OF ESTUARIES

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ABSTRACT

Twelve principal uses are made of estuaries, providing exceptional value to human interests. In the United States every one of these uses is expected to increase in the next 20 years above its present high level. At present, at least 16 major classes of pollutants are placed in estuaries, with effects that range from minor inconvenience to serious reduction in the usefulness of the system for other purposes. Some present pollutants have high potential for beneficial introduction if the quantity, site, and characteristics of the material are appropriate.

In this overview, the uses and pollutants are identified, the trend for each is noted, the principal deleterious effects of pollutants in coastal waters are summarized, and visual summaries are presented to suggest which of the uses may be affected by each class of pollutant.

INTRODUCTION

The purpose of this report is to identify the principal uses of estuaries and the significant pollutants entering estuaries in the United States, and to indicate which of the uses are likely to be affected by each pollutant. It is intended that this information be presented with both technical accuracy and ease of comprehension. Such a summary is necessarily limited to the broad national situation, and must be applied with care and local information to any estuary. The method for such local use will be suggested.

The International Oceanographic Commission (IOC) for the United Nations' Educational and Scientific Commission (UNESCO) defines pollution as: *Introduction by man, directly or indirectly, of substances into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, or hindrance to marine activities (including fishing), impairing the quality for use of seawater and reduction of amenities.* (Ketchum, 1972)

This definition will be used in subsequent discussion, with the interpretations that "substance" includes heat and that the term "oxygen demand" is employed as a short substitute for "substances which increase chemical or biological demand for oxygen."

This definition requires that one of the diverse uses that man makes of the aquatic area is or is likely to be deleteriously affected. Therefore, it seems reasonable and constructive to summarize the uses of the estuary and illustrate which of them might be damaged by each important class of polluting substances.

This presentation draws upon many of the other reports presented at this conference to help identify the principal present uses of estuaries, distinguish the most important pollutants at this time, and discuss some of the significant trends in both uses and pollution.

THE PRINCIPAL USES OF ESTUARIES

The values which estuaries serve in relation to human activities have been summarized rather frequently in recent years, and it is helpful to review the listings developed. They are presented in Appendix A. It is apparent that these lists were prepared for various purposes and from diverse points of view. They have been employed to assist the preparation of a fresh listing which attempts to include all significant uses in the simplest set which is adequate and accurate.

Table 1 presents my listing of principal general uses of estuaries in the United States. Each of these is important to the people of the nation. However, subclasses of some of these uses merit specific attention, even in this national overview, since the effects of pollutants can be substantially different between the subclasses. For instance, recreational use for boating is not likely to be harmed directly by some of the chemical pollutants which may destroy fishing or hunting. Therefore, a limited number of subordinate categories has been chosen and included in Table 2, Principal Specific Uses.

Table 1 —Principal general uses of estuaries

Commercial Shipping	Military Purposes
Shoreline Development	Research and Education
Recreation and Aesthetics	Climate Control
Mining	Biological Harvest
Electricity Generation	Preservation
Water Extraction	Waste Placement

Table 2.—Principal specific uses of estuaries

Commercial Shipping	Water Extraction
Shoreline Development	Military Purposes
A For Residences	Research and Education
B For Industry	Climate Control
C. For Recreation	Biological Harvest
Recreation and Aesthetics	A Food
A Boating	B Industrial Materials
B Swimming, Surfing, Sunning	Preservation
C Hunting	A Species
D. Fishing	B Ecosystems
E Aesthetic Enjoyment	C Productivity
Mining	D Other Features
A Aggregates	Waste Placement
B Oil and Gas	A Human Wastes
Electricity Generation	B Industrial Wastes

The intensity and value of each use varies widely for the 850 estuaries of the nation, and each system merits analysis and management on a specific and individual basis For such analysis, these tables provide checklists to be culled and applied appropriately.

Each of the principal and specific uses is briefly discussed in the following pages, with notes on magnitude and trends if information is available Extensive additional information is available in "The National Estuarine Pollution Study" (Federal Water Pollution Control Administration, 1969) and especially in other papers presented at this conference "The National Estuary Study" of the Fish and Wildlife Service (1970), in its Appendix G, provided predictions (which will be called NES forecasts) of uses for selected estuaries including Penobscot Bay, Delaware Bay, Charleston Harbor, Tampa Bay, Galveston Bay, Newport Bay (Cal), San Francisco Bay, Yaquina Bay, Puget Sound, and Cook Inlet These and other projections are noted below

Commercial Shipping

The estuaries include every port in the nation, since offshore ports have not yet been developed Therefore, all surface import and export, as well as all coastal and local traffic by ships, tankers, and barges, involve estuaries The great coastal cities were sited as they are because of estuarine shipping, and continue to be dependent on such transport Commercial shipping, involving many kinds of vessels, increased substantially in recent decades to a level of 1 6 billion tons in 1972, and is projected to continue that trend in the foreseeable future (Langlois, 1975) The NES forecasts predict increased commercial shipping in all eight case study estuaries (Fish and Wildlife Service, 1970)

Shoreline Development

Construction and other engineering of the shallow floor, shoreline, and adjacent land mass have been intensive around every coastal city, and extensive as thousands of miles of estuarine edge have been modified for residential and recreational use The population of the United States is rapidly shifting to the coastal area with resultant intensification of such development (Belcher, 1975) Exceptional growth in populations is expected to continue in coastal regions (Belcher, 1975), so that such alterations are likely to increase

Conservation has been apparent recently in managing wetland conversion and, indeed, all modifications of estuarine edges This backlash to the almost ungoverned development of such areas is presently slowing the changes The uncertainties of economic probabilities and legislative predilection preclude useful forecasting of specific trends

For Residences

These include permanent homes, part-time cottages, and campsites They frequently involve alterations from grading and construction and the use of bulkheads and piers for land protection and recreation The quality of sites for use for residences usually depends on the aesthetic quality of the estuary and surrounding lands, and secondarily on potentials for such activities as fishing and boating Belcher's summary of recent trends for the eastern seaboard suggests that residential use of estuarine edges is likely to be increased by the shift of population, by more leisure, by early retirement, by the growth of commuting, by the trend toward more dwelling units per family group, and by the quest for a new quality of life with more contact with nature In all of eight specific estuaries, increased residential development is expected (Fish and Wildlife Service, 1970)

For Industry

This development covers waterfront facilities (deepwater, piers, intake and effluent structures, bulkheads, fills and specialized structures) and on-land buildings, transportation systems, utilities, and other appurtenances. No statistical summary of recent and prospective trends is available to me, but future use for these purposes seems likely to be substantially affected by nationwide efforts to zone coastal activities. NES forecasts project greater industrial development in all of the eight example estuaries studied (Fish and Wildlife Service, 1970).

FOR RECREATION

Public and private parks and beaches are included here, as well as camping areas, facilities to support boating, and other installations. The use of estuarine shores and waters for recreation is very large and expected to grow (Kalter, 1975), and the development of associated facilities is expected to follow parallel trends. Kalter summarizes from Adams et al., 1973, relevant data on recreational activity and expected demand in all of the BEA areas adjacent to estuarine zones. This totaled over 500 million activity days in 1972, not all on estuaries. Every activity (boating, swimming, nature walks, fishing, water skiing) is expected to increase from 1972 to 1975 for each of the 37 estuarine areas documented in the 1972 survey. Kalter notes that the demand for facilities is unlikely to vary much from the demand forecast based on population and that facility supply is the balance wheel to the demand. Significant variation is apparent by region and by types of recreation, and change in preference is expected. The national trend of development for this use is strongly predicted. Recreation also is expected to increase in each of the eight case study estuaries in NES forecasts.

Recreation and Aesthetics

Use of estuaries for personal pleasure and refreshment takes many forms in the almost infinite variety of specific situations which exist in, on, and around such bays and waterways. Predictions for continued increases in population movement to, and personal use of, estuarine areas provide similar prediction of greater recreational and aesthetic use. Brief additional comment on each selected subclass of use is appropriate.

BOATING

This category is widely diversified, from dinghys and paddleboats through canoes, rowboats, kayaks, pirogues, small to large outboards, sailing vessels, houseboats, and barges, to yachts from modest to palatial. Kalter reports that 49,045,000 days involved boating in the U.S. BEA areas adjacent to estuarine zones in 1972, and that every area is expected to increase by 1978, with an average of 17 percent. All eight case estuaries are predicted to undergo increased boating (Fish and Wildlife Service, 1970).

SWIMMING, SURFING, SUNNING

The variety of pleasant activities along the beach and in or on water needs no definition. This combination of activities is, according to Kalter, the largest recreational activity in the BEA areas adjacent to estuarine zones, involving at least 250,000,000 person days in 1972. By 1978, increases of 12 percent for swimming and 14 percent for skiing are forecast by Adams (1973).

HUNTING

Waterfowl, shorebirds, game mammals, and reptiles are all hunted for recreation. Irby (1972) notes the dependence of many of these on the estuary and their presence in many different estuarine habitats. Bird hunting can involve use of several estuaries at once since many species are highly migratory and may reproduce, feed and rest on different bodies of water—all of which are necessary. No data are at hand on the extent of use of estuaries for hunting, on recent trends, or on future probabilities.

FISHING

Angling, with gear ranging from the simplest hook and line to the complex rigs used for giant carnivores, is popular on all coasts. Clark (1975) summarizes data from a 1970 survey by the National Marine Fisheries Service to note that 10,000,000 coastal anglers caught 350,000,000 fish along the coasts and 468,000,000 in estuaries—which provide essential support for many or most of the coastal catch. From 1960–1970, participants increased by 50 percent. Additional data provided by Kalter describe 110,000,000 fishing days in 1972 in BEA zones adjacent to estuaries and project a 9 percent increase by 1978. NES forecasts predict greater fishing in all eight sample estuaries (Fish and Wildlife, 1970). Bollman (1975) expects increase in value of the fish caught, of the social activity, and of related goods and services. As with commercial harvests discussed below, it is important to note that estuaries are essential breeding and nursery grounds for most of the coastal species and provide necessary migratory pathways for a wide variety of fish.

Aesthetic Enjoyment

Visual pleasure from water and shores; lazing in the environs of estuary; observing birds, plants and animals; and a great variety of other uses engaging the senses and emotions are widely enjoyed. Counts and measurements of such use are difficult to obtain—and not easily separated from other recreational uses. Kalter provides one index, reporting that nature walks involved over 62,000,000 activity days in 1972 and may increase 14 percent by 1978. As for other uses, fuel expense or shortage may enhance such usage for those nearby, and reduce it for those who must travel.

Mining

Sand, gravel, oil, gas, shell, and commercially useful quantities of various chemicals occur under estuaries as under many other surfaces on the earth. Except for such biogenic deposits as shells of estuarine molluscs or of coral, their presence has no relationship to the existence of the estuaries, with which they are in accidental coincidence. The uses of such materials have varied, and probably will vary, as different materials become useful, as techniques for locating and extracting minable substances are improved and as more easily accessible sources on land become partially or completely exhausted. Estuarine mining is now relatively limited, and Riggs (1975) points out that our knowledge of the potentials of both estuaries and the continental shelves is presently only superficial.

Aggregates

For the purpose of this summary, and at some variance with geological terminology, this includes surface and near-surface sediments, gravels, sands, clays, shells, and chemicals. Biggs describes the huge American demand for some of the materials and the difficulties of making reliable estimates of estuarine production, and notes that increased populations near estuaries are highly likely to increase demand for the exploitation of useful deposits. Shell deposits by oysters, brackish-water clams, and other species have many uses (including that of cultch to assist the production of more shellfish), but some of the massive deposits are apparently showing depletion (Biggs, 1975; Espey, 1975). Special purpose clay mining and extraction of minerals, including precious metals, are known to exist and mining is likely to increase. Salt, sulfur, and potash minerals are primarily associated with evaporite deposits, and Biggs considers the increased extraction of these to be highly probable. Mining is expected to grow in six of eight case study estuaries, and to remain at about the same level in Charleston Harbor and Yaquina Bay (NES forecasts).

Oil and Gas

Extraction of these materials within estuarine areas has been occurring in Louisiana, Texas, and Alaska, at least. No data are available on present and future trends.

Electricity Generation

Direct use of estuarine water for condenser cooling water, the most-discussed use of estuaries in the generation of electricity, was generally avoided as long as utilities could obtain fresh water and eliminate the problems associated with use of saline or brackish water.

Production of electricity may utilize estuaries in several different ways. The most direct use is for condenser cooling in steam electric stations. Water may constantly flow through the system or be withdrawn to make up evaporative losses in cooling towers. The dependence of large nuclear plants on estuaries as the only feasible means of transporting massive containment vessels and other large components sometimes controls the siting of such plants.

Such uses are relatively recent in coastal bays, and no summary of present estuarine use has been seen. Because populations and industrial activities are growing in coastal areas, demand is expected to increase and there have been predictions of as many as 10 large nuclear plants in upper Chesapeake Bay and its tributaries, for instance. Mihursky (1975) notes the recent regulations which may substantially affect the direct usage that such systems will make of estuaries. No simple prediction appears feasible at this time.

Water Extraction

The salt content of most estuarine waters seriously hampers use for drinking water, agricultural irrigation, industrial processing, and other purposes common for fresh water, although all of these occur at some sites, especially in fresh or nearly fresh tidal waters. Such use as that of a heat transfer medium in generating electricity or some other industrial processes is not an extraction but a borrow, since the total quantity is usually returned near the intake.

The principal extractive use of water is from the total watershed of estuaries. Withdrawal may occur for inter-basin transfer (Delaware to the Hudson, Sacramento Valley to Los Angeles, and so on), for irrigation, or for other uses which permanently remove water and may drastically affect the estuary. Uses which involve substantial alteration of the pattern of flow releases into the estuary (damming for hydroelectric generation, water supply, recreation, flood control) are not extractive but may also have important estuarine consequences. These differ from the extensive borrow-and-return pattern of most domestic and industrial use, which has little estuarine effect.

No data are available for estimating present extractions of estuarine water nor for predicting trends.

Military Purposes

These include transportation, firing and ordnance ranges, research on vessels and equipment, filling for air strips and other land use, storage of vessels, vessel construction and maintenance, coastal patrol and its support, and education in naval operations, flying, and related fields. No summary has been seen of the present extent of these uses, although they are obviously large in some bays and estuaries. Prediction is impossible, since extended periods of peace may bring reduction in some of these activities as being unnecessary or inappropriate for estuaries—and escalation toward war would make other considerations relatively trivial.

Research and Education

Research is conducted in estuaries to solve the problems which occur and to broaden understanding. Since estuaries have many problems which are increasingly recognized to be important, there has been rapid increase in the number of projects related to fisheries, waste management, water quality, and the social, economic and legal aspects of estuarine use. In addition, the diversity and dynamicism of the geological, physical, chemical, and biological components of estuarine systems have also attracted growing use as wild laboratories.

Similarly, estuaries are highly used in training students, both in livelihood (fishing, recreational boating, maritime skills, and so forth) and fundamental sciences and arts. Marine and estuarine biology has been the most popular field, and a survey of scientific personnel involved with the eastern estuarine environment indicates that research interests among 644 respondents to 1,200 queries were overwhelmingly biological in 1972 (Kerby and McErlean, 1972). All of the many other fields listed lagged far behind, confirming impressions at conferences on coastal topics.

Recent trends have been for increased research and teaching. Large estuarine research societies now exist, with the umbrella Estuarine Research Federation having about 1,200 members in constituent societies in New England, Middle Atlantic, South Atlantic, and gulf coast regions. Several similar groups have been formed on the west coast. Estuaries will be used extensively for these purposes, but future trends are difficult to predict because most financial support is from state and federal funding, which in itself is presently unpredictable. "The National Estuary Study" predicted increased use for research and education of seven of eight selected estuaries, with continuation at the same level in Galveston Bay (Fish and Wildlife Service, 1970).

Climate Control

Modification of climate is perhaps the most extensive, least measurable, and least priceable use of estuaries. As compared with land masses, they moderate summer and winter temperatures, lag spring and fall temperature transitions, and increase humidity. These substantially affect uses for residential, recreational, industrial, and aesthetic purposes, but the value of such effects is obviously complex and elusive. The trend of this use, if indeed that word is appropriate, is proportionate to the activities listed above. Since they are expected to grow, so too will the importance of climate modification by estuaries.

Biological Harvest

Since estuaries have higher natural rates of production of organic materials than almost any other biological system (Teal and Teal, 1969), large biological populations exist and have been harvested throughout the world. Most of the harvest is achieved by hunting techniques, capturing the yield with little or no investment in cultivation, although management through public agencies and by private efforts exists and may increase. Harvest for food and harvest for industrial materials are not significantly different, despite the different distribution of the products—and consequent difference in the ultimate users. These two subclasses of the biological harvest will be treated together in this brief discussion.

The catch of estuary-dependent species was worth about $660 million at dockside in 1973, about 73 percent of the total commercial fish landings value of $900 million for the United States (Tihansky and Meade, 1975). All of the principal species are useful for food except menhaden, although some of the food species also yield industrial products (bait, meal, shell, and so on). Menhaden, the great industrial species which provides meal, oil, and many chemical products, had a 1973 landing of 1.9 billion pounds, valued at $73 million at dockside (Broadhead, 1975). Both food and industrial species increase at least severalfold in value as they move through processing, distribution, and sales to reach the consumer. Even at dockside values, Bollman (1975) notes that the capital required to produce $660 million would, at 5 percent yield, be about $13.2 billion dollars, an approximation of the value of estuarine fisheries—and of this use of estuaries.

Prediction of use trends for estuarine biological resources is exceptionally difficult. In the "National Estuary Study," increased fisheries were predicted for all of the eight case study estuaries, but this may have mixed estimates of demand with estimates of yield. Broadhead (1975) has stressed the instability of marine populations and the complexity of the factors which may affect abundance. It is not possible to forecast the supply, although demand for both food and industrial harvest will increase.

Preservation

Estuaries contain many biological forms, assemblages, environments, and other features which merit preservation. These have been noted and extensively considered in the volume "Marine and Estuarine Sanctuaries, the Proceedings of the National Workshop on Sanctuaries" (Virginia Institute of Marine Science, 1975). Preservation may be needed to assure the continued existence of a species or system, to protect such a component for future availability, to guarantee the productivity of all or part of an estuarine system or to preserve a unique physical, geological, chemical, or biological feature.

Partial preservation now occurs in various wildlife refuges, sanctuaries, parks, and preserves, but there is no national summary of the quality or quantity of such protection. Those participating in EPA's Conference on Estuary Pollution Control vigorously proposed substantial increase in this use of some parts of the national estuarine complex, and provided detailed guidance for such preservation. Both the Coastal Zone Management Act of 1972 (P.L. 92-583) and the Marine Protection, Research and Sanctuaries Act of 1971 (P.L. 92-532) contain authorization and encouragement for increased preservation in estuaries, so that such use may be expected to grow.

Waste Placement

Waste placement is used with intentional avoidance of the comforting term "waste disposal" since even slight critical thought proves that most of our placement of waste materials has not disposed of them—merely transferred them from one site to another. Estuaries have always received substantial quantities of the materials humans wish to dispose of because (1) estuaries lie in the basin-catching position for all land drainage; (2) population clusters along the coast; (3) the chemistry, geochemistry, and dynamics of estuaries provide large capacities for some wastes without harm, or at least visible harm, to other users; and (4) the magnitude and extent of possible damage from wastes was not even partially known until recent decades. The cheapness, convenience, and capacity of estuaries for receiving wastes favor their use within appropriate limits—the extraordinary values, dispersive nature, and relative fragility of the biological systems require conservative use for such purpose.

Human Wastes

At source, human wastes are already complex. Undigested foods and liquid products of metabolism, neither of which is chemically simple, are quickly mixed with shower and bath water, kitchen wastes, washings, and anything else put in the toilet or sink. In systems for sewage collection and treatment, these are frequently combined with industrial wastes and, intermittently, with surface runoff from storms. Even after some degree of treatment, such wastes are usually composed of many materials. For instance, the discharge from the Hyperion and White Point outfalls on the west coast contains more than 20 components to a level of a ton or more discharged per day to the receiving waters. The specific composition of the discharge varies principally with the sources of waste and the kind of treatment, generally but imprecisely described as none, primary, secondary, or tertiary (advanced). No operating plant completely removes all potential pollutants from domestic wastewater except on an experimental or pilot scale.

The magnitude of such wastes is difficult to estimate. As an example, a recent inventory of sewage treatment plants for Chesapeake Bay (Brush, 1974) identified 243 such plants, of which 35 provided primary treatment and 208 were secondary. The total effluent was estimated to be 2.8 percent of

Table 3.—Generated municipal wastes

	1960	1970	1980	Increase 1970–1980
Wastewater, billion gallons	1,612	1,902	2,131	229 or 12%
Standard BOD, millions of pounds	2,230	2,632	2,974	342 or 13%
Settleable and suspended solids, millions of pounds	2,686	3,171	3,551	380 or 12%

the average freshwater flow into the bay. Without similar data from other estuaries, national summation is impossible, but the use is obviously a very large one.

Trends will be affected by the developing pressures from population increase and the changing constraints through regulation. The first of these has been briefly described above, and the very great changes in national regulations have been summarized by Hargis (1975). "The National Estuarine Pollution Study" (1969) quoted (P IV-334) from a FWPCA publication "The Cost of Clean Water" that the national estuarine population would generate the following quantities of several components in the areas served by sewers.

No certain prediction is possible, because economic, political and environmental efforts are all likely to be intense. The outcome cannot be foreseen.

Industrial Wastes

The composition of unwanted materials from commercial activity is as variable as the industry. (See "The National Estuarine Pollution Study," 1969, pp. IV-386 to IV-389, Volume II, for a catalog of such wastes, their characteristics, and the distribution among the states.) Through most of the industrial period in this country, industries were permitted to take full advantage of the economy of placing wastes in nearby waterways as long as they did not endanger human health or cause quite obvious damage. Change in public knowledge and concern in recent decades has brought all new industry, and much old, under considerable control in this regard. As a result of this transition, waste placement has been drastically reduced, although there are residual uses in the forms of (a) contaminated deposits from previous activities, (b) uncorrected violations of regulations, and (c) transport of wastes short distances to the oceanic water as a means of disposal.

The Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500) direct use of "best available" control technology by July of 1977, "best achievable" by July of 1983, and states a national goal of eliminating all pollutant discharge.

THE REAL WORLD OF USES

Rarely, if ever, is an estuary utilized significantly for only one of the uses noted above. Even primitive populations of low technological capability are likely to fish, use boats, place wastes, and recreate in such waters. This, then, is the simplest form of multiple use, and the most complex form occurs in the harbors of industrialized cultures with large populations, where every listed use may be occurring at once. The problem lies in the fact that almost every use can become so large that it impinges upon other uses and users.

Several interesting and potentially useful concepts for managing uses of estuaries have received recent attention and may become incorporated in coastal zone management. One may be called an exclusion concept, which dictates that the exceptionally valuable shoreline will be reserved for those uses which are genuinely dependent on such siting—and excludes those which are not. For instance, docks, swimming beaches, and large marine railways can only exist at the edge of water. Processing plants (even for seafood), power generating stations, and oil refineries can frequently be sited as well, or better, away from the estuary. Such siting may become mandatory. Another concept receiving present currency is that of clustering of uses, an intense form of zoning. If industrial activities are concentrated, the argument runs, efficiencies are possible in providing utilities, handling wastes, and arranging transportation, as well as in surveillance and enforcement. With clusters, more of the total estuarine shoreline is left without problems of such use. These concepts, and many additional ideas, seem likely to receive increased attention as the task of balancing uses, the focal thrust of the Coastal Zone Management Act of 1972 (P.L. 92-583), is implemented.

It is appropriate to note, in this discussion of the interactions of pollutants with the uses of estuaries, the obvious but very important fact that use is usually the source of pollution. Most, but not all, of the listed uses have this potential. Change in usage or change in the regulation of pollution can have major effects on each other.

The large task is that of achieving, through sufficient knowledge and wise government, the optimal balancing of multiple uses of estuaries so that they serve the public interest most effectively. To achieve this, all human activities must be constrained so as to remain within the inherent capacities of the estu-

Table 4 —Principal pollutants of estuaries

Pathogens	Brine
Sediments	Toxic Inorganics
Solid Wastes	Toxic Organics
Color Sources	Petroleum
Odor/Taste Sources	Nutrients
Floatables	Radioactivity
Heat	Oxygen Demand
Freshwater	Acids and Bases

arine system—lest they destroy the system and its uses

THE PRINCIPAL POLLUTANTS OF ESTUARIES

Introductions by human activities which can be damaging in estuaries have been cataloged several times, and some recent lists are provided in Appendix B Taking advantage of these summaries, a new listing of 16 pollutants has been prepared, again attempting to include all significant introductions in the simplest set which is both accurate and adequate (Table 4) Each of these is defined or described, and references are provided to selected papers which contain information on the quantity and probable future trend of each

Pathogens

Living organisms which can cause pathology or sickness in either the animals and plants within the estuary or in humans who eat or contact materials taken from the water include a wide variety of bacteria, protozoa, viruses, and fungi Human pathogens are frequently abundant in sewage, but may enter the water from other waste disposal or from accidental spills. The pathogens of aquatic species are often introduced with transplanted organisms, and are often indirectly affected by environmental alterations such as salinity increase or decrease See· Colwell, 1975, Ketchum, Ed , 1972, McEwen, 1972, "National Estuarine Pollution Study," 1969, Sindermann, 1972

Sediments

Inorganic particulate materials ranging in size from clays and silts up to at least sands may occur in many forms, from essentially single-size loads to extremely complex mixtures of particles with loose and firm aggregates containing many materials. Estuaries are inherently sediment traps, but the effects of man's activities through practices in forest clearing and agriculture, surface alterations in urbanization, mining activites, channelization, poor sediment control during construction of roads and other facilities, excessive enrichment, solid waste placement, and dredging and spoil placement have massively increased the rate and quantity of sediment input, deposit, resuspension, and redistribution in many of the nation's estuaries Storage reservoirs and improved land management practices have sometimes effectively reduced sediment input See. Boyd et al, 1972, Carpenter, 1975, Committee on Water Quality Criteria, 1969, Hedgpeth, 1975, Hood, 1975, Lee, 1975, "National Estuarine Pollution Study," 1969; Schubel, 1975

Solid Wastes

Accumulated unused solid wastes are presenting one of the serious problems of all urban, and many suburban, areas Domestic materials, agricultural wastes, and, especially, industrial unused products are involved Estuarine placement has been widely used as one of the alternatives, with placement ranging from dumps in the marsh and edge of the river to ship transport to deeper water. The composition of such materials defies single description, and the effects include those of sediments, toxicants and many other pollutants See· Committee on Water Quality Criteria, 1972, Feibusch, 1975, Gross, 1969, Hood, 1975, Smith, 1975

Color Sources

Natural sources of color in estuarine waters include leachates from marshes, swamps, and other vegetative areas, suspended particles, and blooms of plankton. Human effects on color are most likely from industrial effluents or accidental spills Color is not toxic, but affects the quality and quantity of light penetration and availability, and the material causing color may have additional effects

Odor/Taste Sources

Many materials can affect the odor or flavor of edible (to humans) estuarine products or the aesthetic quality of the estuarine environment. They are primarily organic, and the most common are oils and petroleum products Little is known about the effects of various materials on the edibility of estuarine species by other species, although it is reasonable to suspect that it occurs and may be important The effect on human seafoods is economic, since the presence of offensive odor or taste usually prevents eating sufficient quantity to cause illness. See: "The National Estuarine Pollution Study," 1969.

Floatables

Low-density materials on the surface may be in the form of slicks, globs, wood and fibrous organic material, undigested plastics of many types, rubber goods, sealed bottles or cans and many other substances which are either inherently light or capable of holding gases. They occur on the surface and usually move to the shoreline. See: Pearson, 1975.

Heat

Heat is introduced into the estuary from condenser cooling in power plants, cooling by other industry, and in relatively small amounts incidentally with other waste discharges. After initial warming, the receiving waters act essentially as a transfer medium, conveying virtually all introduced heat to the atmosphere. This release may involve extremely large estuarine areas, because of dispersion by tidal flow and mixing processes. See: Blake, 1975; Committee on Water Quality Criteria, 1972; Clark and Brownell, 1973; Cronin, 1975; Hedgpeth, 1975; Jensen 1975; Mihursky, 1975; Smith, 1975; Water Resources Criteria, 1972.

Fresh Water

Damaging introductions of fresh water resulting from man's activities can result from opening of spillways and diversion channels, release of large volumes of low salinity effluent in water of higher salinity, and land use practices which permit flashier runoff than would have occurred under natural regimes. See: Cronin, 1967; Smith, 1975.

Brine

Salt in detrimental concentration may be introduced as true brines from industrial activity or from blowdown residues in cooling towers. It may also be added in more dilute form observable as salinity increase above that which would have occurred without human causes. This can be caused by diversion of freshwater from the watershed for consumptive uses like inter-basin transfer, irrigation, or evaporative cooling towers; by deepening of channels; by up-stream release of condenser cooling water; and by other mechanisms. See: Hedgpeth, 1975; Schubel and Meade, 1975; Smith, 1975.

Toxic Inorganics

Although every inorganic element or compound can be toxic at some level of concentration and exposure, attention is usually most appropriate for those of exceptionally high toxicity or probability of release. Thirty-five to 40 elements and a much larger number of compounds are known to be potential serious pollutants. These exist in industrial effluents, domestic waste treatment effluents, biocides (especially as the result of chlorination), drainage from mines or quarries, and many other sources. Especially thorough summary has been presented by the Committee on Water Quality Criteria, 1972. See: Blus et al. 1975; Committee on Water Quality Criteria, 1972; Hedgpeth, 1975; Hood, 1975; Ketchum, Ed., 1972; Middaugh and Davis, 1975; "National Estuarine Pollution Survey," 1969; Smith, 1975.

Toxic Organics

Most of the especially toxic organic compounds turned loose in estuaries are synthetic compounds, and the most serious are those which are highly persistent. They arise primarily from the wide range and large quantities of biocides employed on land (fungicides, herbicides, insecticides, rodenticides) but also from additional halogenated hydrocarbons, petroleum, and industrial chemicals. The nature and experimental toxicity of these creations of man have been detailed by the Committee on Water Quality Criteria, 1969. See: Blus et al. 1975; Butler, 1975; Committee on Water Quality Criteria, 1969; Hedgpeth, 1975; Ketchum, Ed., 1972; Lincer, 1975; Smith, 1975; Walsh, 1972.

Petroleum

Petroleum and its complex components are principally organic but the extraction, transportation, handling, refining, and distribution of these fossil energy sources have created a distinctive set of problems in pollution. Since estuaries are the waters of entry, and petroleum pollution is highly associated with transporting, handling, and refining, considerable concern exists and will continue. See: Blus et al. 1975; Brown, 1975; Committee on Water Quality Criteria, 1972; Farrington, 1975; Hedgpeth, 1975; Hood, 1975; Ketchum, Ed., 1975.

Nutrients

Nutrients are the chemical raw materials which are essential for biological processes. These enhance productivity in appropriate quantities but can seriously disrupt the estuarine ecosystem through excessive enrichment Nitrogen, phosphorous, and carbon are the most noted specific elements, but less abundant elements and compounds can be significant Polluting quantities can be introduced from sewage effluent, runoff from cleared or agricultural land, detergents, street runoff, and industrial wastes As eutrophication occurs with increasing frequency and at additional locations, many consider these additions to present one of the most serious threats to best use of estuaries See · Champ, 1975, Committee on Water Quality Criteria, 1972, Hobbie and Copeland, 1975, Ketchum, Ed , 1972, Pearson, 1975; Smith, 1975

Radioactivity

Radioactive elements and compounds can enter the estuary from fallout from atmospheric burden, from testing of weapons and other uses, release of wastes from nuclear power plants and other users of such fuels, drainage of mines, accidental spillage in hospitals, and with wastes from reprocessing plants and some industries. Because of increased introduction, longevity of emission, and the knowledge that it can cause somatic and genetic damage in estuarine biota and possibly in humans, this relatively new pollutant is of national significance. See · Committee on Water Quality Criteria, 1972, Ketchum, Ed , 1972; National Academy of Sciences-National Research Council, 1971.

Oxygen Demand

Some additions can create additional demand for the finite quantity of oxygen in estuarine water Sewage sludge, wood wastes (pulp, bark, chips), sediments stirred during dredging operations, and the secondary effects of excessive enrichment can all contribute to this demand Freshwater management practices which increase vertical stratification during periods of high temperature will enlarge the area and volume of oxygen depletion in some estuaries See · Committee on Water Quality Criteria, 1972; Hood, 1975; Ketchum, Ed , 1975, Pearson, 1975

Acids and Bases

A complex carbon dioxide-bicarbonate-carbonate system buffers estuarine waters to help stabilize them against change from the addition of acidic or basic chemicals The buffering capacity can, however, be exceeded by large additions, and thus would dangerously alter the environment of the biota, which cannot survive much change of this kind In addition, the toxicity of most other pollutants increases under such circumstances Acids or bases might reach the estuary from mine drainage, accidental spills, or industrial wastes See Committee on Water Quality Criteria, 1972

THE EFFECTS OF POLLUTANTS*

The introduction of a chemical compound or a change in the physical environment may affect a natural marine ecosystem in many ways In coastal waters undisturbed for long periods of time, the ecosystem has adjusted to the existing conditions The system is productive, species are diverse, the biomass is high, and the flow of energy is comparatively efficient The addition of pollutants to such a system might.

- reduce the input of solar energy into the ecosystem,
- increase the input of organic matter and nutrients which might stimulate the growth of undesirable species,
- reduce the availability of nutrients by increased sorption and sedimentation,
- create intolerable physical extremes for some organisms, as by the addition of heat,
- kill or reduce the success of individual organisms, as by lethal toxicity or crippling with oil,
- eliminate species by adding a toxic material or making an essential element unavailable,
- interfere with the flow of energy from species to species, as by a chemical that interferes with feeding behavior,
- reduce species diversity in the system,
- interfere with regenerative cycling by decomposers,
- decrease biomass by reduction of abundant species or disruption of the processes of ecosystems,
- increase biomass by removing important consumers, allowing runaway production of other species

All of these may involve changes in production and lowered human usefulness of the system These are examples, additional effects can occur The specific impacts of pollution at a site can be determined only through long-term study of that portion of the ocean and the changes that occur

* Verbatim from Committee on Water Quality Criteria, 1972, pp 219–220

VISUAL SUMMARY OF THE INTERACTIONS BETWEEN POLLUTANTS AND USES

Matrix charts have been prepared to suggest which of the uses are likely to be significantly affected by each pollutant (Figures 1 and 2). A simple set of symbols was selected, so that:

Black: Danger, this pollutant can have serious effects on that use.

Hatched: Caution, this pollutant may in some circumstances reduce that use.

Grey: This pollutant can be beneficial to that use in favorable circumstances.

Blank: No substantial effect is known to occur.

As with all efforts to reduce massive complexity to an unqualified simple summary, the viewer shares some of the responsibility for preventing mis- or over-interpretation. The following qualifying comments may help:

1. *The selection of signals is subjective*, not quantitative. It is based on about 35 years of scientific experience with estuarine pollution, participation in several of the panels cited, and the advantage of excellent reports prepared by many expert specialists.
2. *The time scale is difficult to handle.* As regulations are changed, or enforcement is modified, or new knowledge emerges, the real threat from a pollutant is altered. So, too, may the importance of a use vary with time. These estimates apply to 1975.
3. *Each estuary is unique.* This matrix intentionally stresses the most likely interaction among the 850 or more such systems in the nation, but each case can be effectively understood only on its own terms. Perhaps the matrix can best be posed as a series of questions for each estuary—"Is this pollutant reasonably likely to have the suggested effect on that use? If not, what is the real local relationship?" At least, a useful set of questions may be summarized in the matrices.

In most cases, it is probably easy to comprehend the opinion of the author, but one set of symbols requires explanation—those under the use of Research and Education. While the presence of a pollutant offers opportunity for study and for teaching, that interaction was not chosen for emphasis. Rather, the symbol indicates how the pollutant is expected to affect research and education on the basic nature, components, processes, and systems of estuaries—and many of the pollutants might either interfere with or substantially enhance such research and the effective education of students.

These matrices may have several uses. They suggest which pollutants are potential threats to the fewest and to the most uses, and which face the largest and smallest number of probable sources of damage—and all of the intermediate probabilities. Thus, they may help in identifying the pollutants of highest priority for control in national, regional, state, or local programs. In any one estuarine system, selection of the uses most valuable to, or preferred by, the people of the region can be followed by preliminary identification of the most probable sources of destruction for those uses. Such a preliminary identification from these matrices would, of course, be but the first step in constructive local efforts to assure good balance. One of their most stimulating aspects is the display of many potentials for constructive use of possible pollutants—of conversion of problem materials into positive resources. If preparation of these summaries facilitates that necessary process, value will have been achieved.

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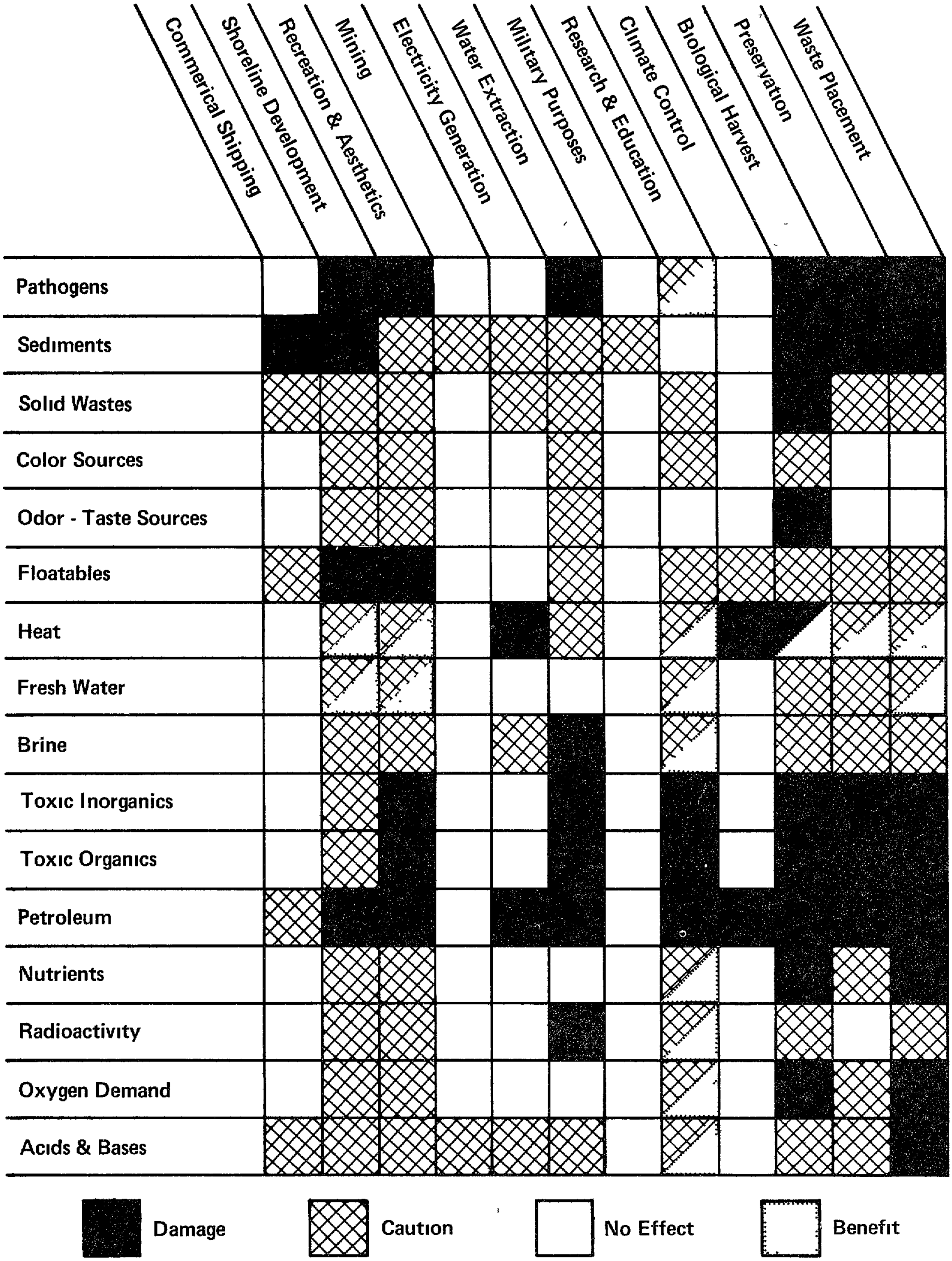

FIGURE 1 —Probable effects of pollutants.

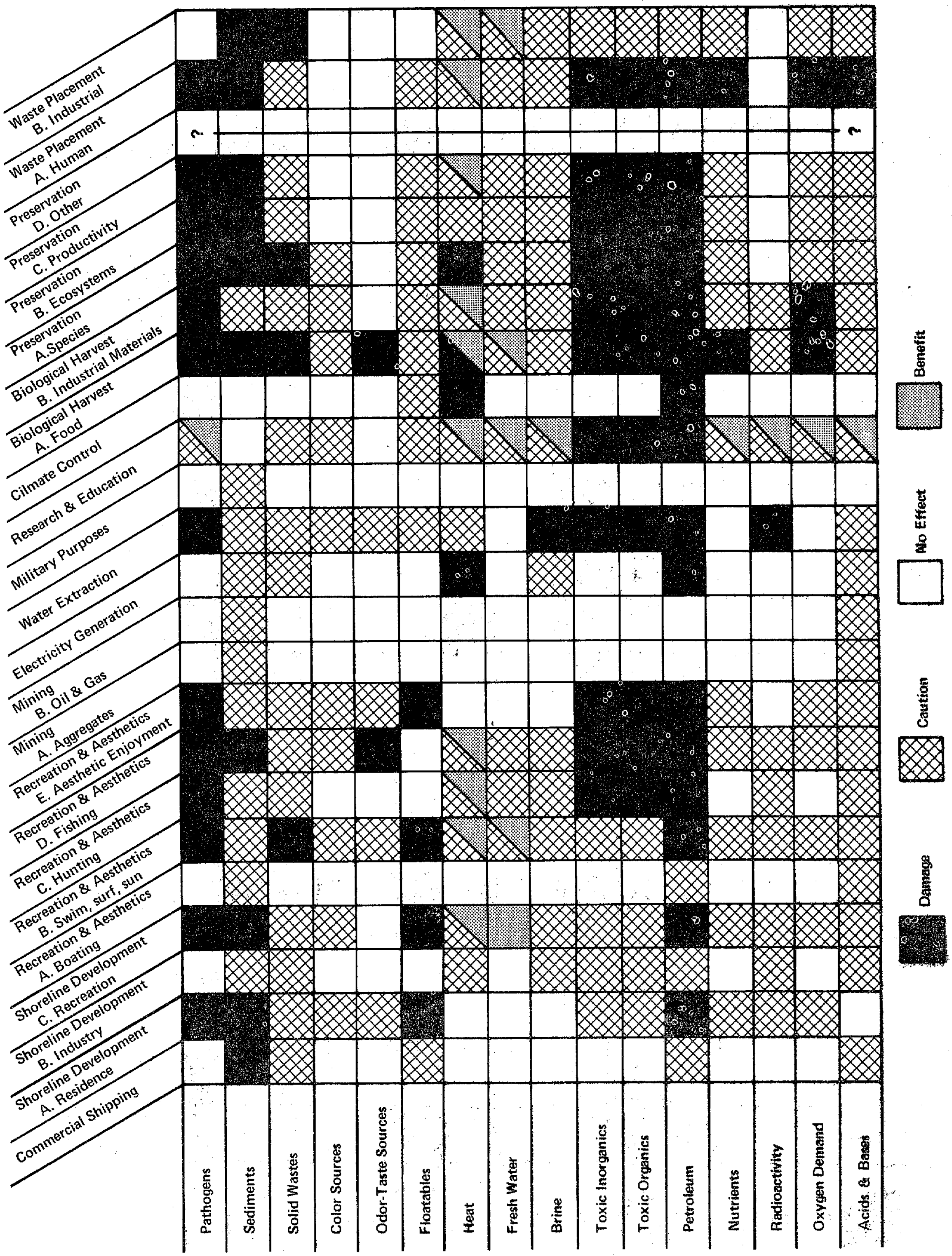

FIGURE 2.—Probable effects of pollutants on the uses of estuaries.

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Center for Environmental and Estuarine Studies, University of Maryland Contribution No 653

APPENDIX A

Previous Lists of Uses of Estuaries and Coastal Waters (Chronological order)

Batelle, 1966 In Development Potential of U S Continental Shelves ESSA, Dept Commerce (Cited from Teeters 1968)

Mining and Petroleum
Marine Engineering
Recreation
Health and Welfare
Transportation
Food and Agriculture
Defense and Space
Research and Development
Other Industry

The original report noted 51 specific uses under these categories

Resources for the Future, 1967 In National Interests in the Marine Environment (Cited from, and as modified by, Teeters 1968)

Economic Development
- Resource Development
- Transportation and Communication Facilities
- Recreation
- Disposal of Wastes

National Security
- Defense of U S Territories
- Support of U S Forces

Promotion of Cultural and Social Values
- Research and Development
- Preservation of Natural Beauty
- Enjoyment of the Environment

Cosrel, 1968 "Coordinating Governmental Coastal Activities" (Cited from Teers 1968)

Resources
- Animal
- Non-living
- Vegetable
- Energy (tidal)
- Repository for Wastes

Enjoyment
- Recreation
- Aesthetic

Transportation
- Sea-oriented
- Land-oriented

National Defense
Land and Sea Use
- Private
- Commercial
- Industrial
- Military
- Other

Ipon, 1968. "Identification of Problems and Opportunities and Needs, Existing and Potential" (Cited from Teeters 1968)

Urbanization
Industry
Transportation
Mining
Waste Disposal
Pest Control (predominantly insects)
Defense
Agriculture
Power Production
Water Supply
Recreation
Commercial Fishing
Research and Education

The National Estuarine Pollution Study, 1969 Volume I, Part 2, pp 30–44

Fishing
Recreation
Transportation and National Defense
Municipal and Industrial Water Supply
Waste Disposal
Exploitation of Mineral Resources
Aquaculture
Shoreline Development

Ketchum, B H , 1969

Swimming
Boating
Sportfishing
Commercial Fishing
Boat Yards and Marinas
Housing
Land Fill and Development
Marine Transportation
Dredging and Filling
Industry
Mining and Petroleum

National Estuary Study, 1970 Appendix F, pp 6–7

Water Transportation
Commercial Fisheries
Extractive Industries
Water Utilization and Estuarine Discharge
Urbanization
Recreation
Research and Education

National Estuary Study, 1970 Appendix G

Commercial
Deep-draft Transportation
Boating
Mining and Minerals
Fisheries
Wildlife
Waste Disposal
Recreation
Aquaculture
Residential
Industrial
Education-Research
Water Supply
Agriculture
Defense
Power Production
Log Storage

Lill, Gordon, 1970(?). For California Advisory Committee on Marine Resources (These are apparently more accurately called activities than uses)

Policing, Control, Inspection, Regulation
Breakwaters, Dredging, Coastal Maintenance
Right of Way, Easements, Access Roads
Commercial Harbors and Terminals
Shipping
Commercial Fishing
Kelp Harvesting
Shellfish Farming
Sand and Gravel Production
Petroleum Production
Nuclear Power and Desalination Plants
Non-petroleum Offshore Platforms and Other Construction
Federal Government Reservations
Public Coastal Parks
Public Underwater Parks
Underwater Research Parks Assigned Use
Resorts
Housing and Other Real Estate Development
Swimming, Surfing, Water Skiing, Sunbathing
Surf fishing
Boat Sport Fishing
Marinas and Recreational Boating
Waste Disposal

Coastal Zone Workshop on Critical Problems of the Coastal Zone, 1972. Discussion topics

Food
Waste Disposal
Mining and Extraction
Recreation and Aesthetics
Commerce (Transportation)
Habitation (Human)
Scientific Preserve
Industrial Land Use
Power Production
Water and Chemical Extraction
Military Uses
Species Preservation

The Water's Edge: Critical Problems of the Coastal Zone, 1972. p. 13 of Summary of Results and Conclusions

Living space and Recreation
Industrial and Commercial Activities
Waste Disposal
Food Production
Natural Preserves
Special Governmental Uses

The Water's Edge: Critical Problems of the Coastal Zone, 1972. Uses discussed in various chapters.

Living Resources
  Commercial Fisheries
  Sport Fisheries
  Aquaculture
Non-renewable Resources
  Petroleum and Natural Gas
  Sand, gravel and shell
  Minerals
Recreation and Aesthetics
  Swimming
  Surfing
  Skin Diving
  Pleasure Boating
  Sport Fishing
  Tourism and Recreation
  Coastal Preserves
Urbanization and Industrial Development
  Housing
  Industrial Development
  Energy Needs
  Government Uses
Transportation and Coastline Modification
  Shipping and Commerce
Waste Disposal

Ellis, Robert N., 1973. Uses of Chesapeake Bay

Waste Disposal
Wetlands (Natural Production)
Commercial Fishing
Water Supply
Commercial Marine Transportation
Recreation
Shoreland Residential Development
Shoreland, Commercial/Industrial Development
Preservation
Mineral Resources

Clark, John, 1974. Coastal ecosystem uses

Aesthetics
Commercial Fishing
Mining
Mariculture
Transportation
Utilities
Recreation
Residential Construction
Preservation of Fish and Wildlife

EPA, 1975. Conference on Estuary Pollution Control—Uses listed for discussion

Waste Disposal
Sport Fishing
Commercial Fishing
Mining
Transportation
Electric Generation
Wildlife
Recreation

APPENDIX B

Previous Lists of Pollutants of Estuaries (Chronological Order)

The National Estuarine Pollution Study, 1969. Volume I, Part 2, pp. 52

Decomposable Organic Material
Flesh-tainting Substances
Heavy Metals
Mineral Salts
Pathogenic Organisms
Toxic Materials
Thermal Pollution
Sediment
Oil

Wastes Management Concepts for the Coastal Zone, 1970. Provides discussion on the following:

Pesticides
Sludges and Solid Wastes
Heat
Oil
Toxic Substances
Nutrients
Dissolved Organics
Oxygen Demand
Brine
Fresh Water

The Water's Edge: Critical Problems of the Coastal Zone, 1972. Considered to be of special concern:

Trace Metals
Plant Nutrients
Organic Additions
Solid Wastes
Radioactivity
Pathogens
Heat
Dredging, Filling, Marine Mining

Water Quality Criteria, 1972. Principal categories considered by the Panel on Marine Aquatic Life and Wildlife

Temperature
Inorganics (including Heavy Metals and factors affecting pH)
Oil
Toxic Organics
Oxygen Demand
Radioactive Materials
Sewage and Nutrients
Solid Wastes

Clark, John, 1974. Environmental Events

Biological Oxygen Demand
Dissolved Oxygen
Nutrients
Pathogens
Floatables
Odors and Tastes
Color
Toxicity
Dissolved Salts
Radiological
Temperature
pH Buffering
Ground Water

EPA, 1975. Conference on Estuary Pollution Control. Pollutants listed for discusssion

Oil
Solid Wastes
Sediments
Nutrients
Sewage
Heat
Synthetic Organics
Metals
Chlorination
Bacteria and Viruses
Agricultural Wastes

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